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WILLIAM EMERSON RITTER

EDITOR

VOLUME 3

WITH 34 PLATES

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CONTENTS.

		PAGE
No. 1.	Some Observations on the Nervous System of Copepoda, by Calvin Olin Esterly. With Plates 1 and 2	1–12
	Introduction	1
	Methods	2
	Results	3–5
	Summary	5–6
	Bibliography	7–8
	Description of Plates	10–12
No. 2.	Ostracoda of the San Diego Region. I. *Halocypridae*, by Chancey Juday. With Plates 3-7	13–38
	Introduction	13
	Key to Genera and Species	14
	Description of Genera and Species	15–28
	Bibliography	29
	Description of Plates	30–38
No. 3.	The California Shore Anemone, *Bunodactis xanthogrammica*, by Harry Beal Torrey. With Plate 8	41–46
	Introduction	41
	Generic and Specific Description	42–45
	Description of Plate	46
No. 4.	Sexual Dimorphism in *Aglaophenia*, by Harry Beal Torrey and Ann Martin. With 9 text figures	47–52
	Discussion	47–51
	Bibliography	52
No. 5.	Additions to the Copepod Fauna of the San Diego Region, by Calvin Olin Esterly. With Plates 9-14	53–92
	Introduction	53
	List of Species	54
	Descriptions of Genera and Species	55–77
	Appendix, List of Species which have been described since 1897 in the genera listed in this paper	78–79
	Bibliography	80–81
	Explanation of Plates	82–92
No. 6.	*Dinoflagellata* of the San Diego Region. II. On *Triposolenia*, a New Genus of the *Dinophysidae*, by Charles Atwood Kofoid. With Plates 15-17	93–116
	Introduction	93
	Morphology of *Triposolenia*	94–101
	Generic and Specific Descriptions	101–110
	Bibliography	110
	Explanation of Plates	112–116

PAGE

No. 7. A Discussion of Species Characters in *Triposolenia*, by Charles Atwood Kofoid 117–126
The Nature of Species Characters 117–120
Analytical Table of Characters 119
The Adaptive Significance of Species Characters discussed 121–124
Coincident Distribution of Related Species in Triposolenia 124–125
Bibliography 126

No. 8. On the Significance of the Asymmetry in *Triposolenia*, by Charles Atwood Kofoid. With 2 text figures 127–133

No. 9. *Ostracoda* of the San Diego Region II. Littoral Forms, by Chancey Juday. With Plates 18-20 135–156
Introduction 135
Family *Cytheridae* 135–138
Family *Cypridinidae* 138–147
Family *Rutidermatidae* 147–149
Note on the *Halocypridae* 149
Bibliography 150
Explanations of Plates 152–156

No. 10. *Cladocera* of the San Diego Region, by Chancey Juday. With 1 text figure 157–158

No. 11. The Marine Fishes of Southern California, by Edwin Chapin Starks and Earl Leonard Morris. With Plate 21 159–251
Introduction 159–160
Discussion of Species 161–247
Bibliography 248–251

No. 12. Biological Studies on *Corymorpha* II. The Development of *C. palma* from the Egg, by Harry Beal Torrey. With 33 text figures 253–298
Introduction 253–254
The Medusa, Eggs, and Egg-laying 254–257
Segmentation of the Egg; the Embryo 257–258
The Larva 258–264
Locomotion 259
Polarity 259–261
Establishment of Body Regions. Elongation of the Stem 261–263
Development of Tentacles 264–272
Development of Frustules 272–278
Metamorphosis 278
Recession of the Perisarc 279–281
Development of the Axial Parenchyma 281–291
Division of the Hydranth Cavity 291
The Gonosome 291–292
Summary and Conclusions 292–296
Bibliography 297–298

PAGE

No. 13. *Dinoflagellata* of the San Diego Region III. Descriptions of New Species, by Charles Atwood Kofoid. With Plates 22-33 299–340
Introduction 299
List of Species 299–300
Descriptions of Species 300–315
Bibliography 316–317
Explanations of Plates 318–340

No. 14. The Structure and Movements of *Condylostoma patens*, by John Freeman Bovard. With Plate 34 and 20 text figures 343–368
Introduction 343
Structure 344–350
General Description 344–345
Ectoplasmic Structures 345–350
Pellicula 345
Surface Markings 345–346
Myonemes 346–347
Cilia 347–348
Membranellae 348–349
Undulating Membrane 349
Buccal Groove 349–350
Locomotor Movements 350–366
I.—Gliding 350–356
Parts of the Body concerned 351
Position of the Body 351–354
Rate of Gliding 354
Direction of Gliding 355
Direction of Movement in Cut Pieces 355–356
Summary 356
II. Swimming 357–359
III. The Motor Reaction 359–364
IV. The Motor Reaction in Cut Pieces 364–366
General Summary 366
Literature Cited 367
Explanation of Plate 368

Index to Volume 3 369–383

UNIVERSITY OF CALIFORNIA PUBLICATIONS
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SOME OBSERVATIONS ON THE NERVOUS SYSTEM OF COPEPODA

BY
C. O. ESTERLY

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SOME OBSERVATIONS ON THE NERVOUS SYSTEM OF COPEPODA

BY

C. O. ESTERLY.

The question of the innervation of the sensory hairs of Arthropoda has long been under discussion. This may be said to hold both for auditory and other sensory hairs of higher Crustacea and Insecta and for the bristles and aesthetasks on the antennae of Entomostraca. Claus ('60) claims that a nerve fibril can be traced into the appendages on the anterior antennae of Cyclops, and later he establishes this for other animals. Vom Rath ('87), ('88), ('91), without distinguishing sharply between auditory and tactile bristles, states that for every olfactory and tactile (auditory) bristle there is a group of bipolar ganglion cells. Each of these cells gives off a peripheral fibre which after union with similar fibres from the other cells of the same group, forms a strand that enters the hair and ends only at its tip. Claus ('91) agrees with vom Rath in the main but holds that there is only one ganglion cell to a bristle.

On the other hand, Retzius ('92) was unable to trace the peripheral fibres farther than the base of the hair, and he found several ganglion cells to each hair. Bethe ('95) states that in the otocyst of Mysis there is one cell to each auditory hair, and that the peripheral process extends only into the base of the hair shaft. Prentiss (:01) has shown that in the case of the otocyst and tactile hairs, the terminal fibre of "the single nerve element" ends in the base of the hair shaft without branching. The olfactory bristles, however, receive a peripheral strand gathered from

as many as a hundred cells, which "extends some distance into the cavity of the hair," to end there without any modification.

From this very brief review it will be seen that the facts concerning the innervation of the sensory hairs of Crustacea are considerably confused. The peripheral endings of the nerves of the bristles and aesthetasks are not completely understood nor is it known whether the manner of innervation is the same for all hairs. Vom Rath holds that organs differing as widely in function as auditory and tactile bristles and "sense-clubs" (aesthetasks) are innervated in the same way.

In the present preliminary paper it is intended to report first a few facts concerning the peripheral nervous system of fresh-water Copepoda, and, second, an observation on the structure of the central nervous system.

This work was done partly at Harvard University and partly at the University of California. It is a pleasure to acknowledge the helpful direction of Prof. E. L. Mark of Harvard and of Prof. C. A. Kofoid of California.

The papers of Claus ('60), Richard ('91), and one by Lepeschkin ('98) are the most important ones known to the author which deal specifically with the nervous system of Copepoda, though Retzius ('95) and vom Rath ('91) say incidentally that they have found certain facts to be true in the case of these animals. Lepeschkin ('98) has used the methylene blue method and reported his results but I have not seen his paper; and Kotte (:03) states that he has obtained nerve fibre impregnations in Copepods by allowing the animals to remain in a "weak solution" of methylene blue for several days.

I have been able to obtain excellent staining of certain elements in the antennae of *Diaptomus* by the use of a 1/100 solution of methylene blue in water. The appendages have been studied before and after fixation of the stain, and the results of the two times agree in essential particulars. The methods of fixation were the methylal method recommended by Parker ('92) and his corrosive sublimate alcohol method (Parker '97, p. 4). There is little difference, if any, in the results obtained from these methods.

It is known, chiefly from the publications of Schmeil ('96), that certain of the joints of the anterior antennae bear the modified sensory bristles or aesthetasks (sense-clubs, Riechschläuchen). In my methylene blue preparations it can be seen that in each joint which carries an aesthetask there is a group of cells, each cell giving off a peripheral fibre which unites with those of the other cells to form a single strand (Pl. 1, fig. 1). This enters the sense-club where it terminates in fine fibrils (Pl. 1, fig. 5). These do not seem to lie free in the interior of the club, but upon its extremely delicate walls.

The number of cells in the groups varies somewhat, but there are always more than one, and seven is the largest number seen in one group. The groups of cells always lie in the segment carrying the aesthetask which they innervate, and they are always proximal to the sense organ; that is, the strand formed by the union of the peripheral processes of the cells passes toward the distal end of the antenna to enter the sense-club.

Little more can be said at present as to the structure of the ending within the aesthetask than that in the majority of cases, both before and after fixation, there is a heavily staining globule just at the point where the sense organ begins to broaden out from the narrow stalk-like basal portion (Pl. 1, figs. 2, 5). Beyond this body the terminations seem to be of the ordinary fibrillar type. There is some evidence, based on staining reactions, that there are two sorts of cells in the group. This appears both in fresh and fixed preparations. Some cells stain more lightly than others, but both send processes to the sense organ (Pl. 1, figs. 1, 6, 8). There is an indication that one sort of cell is unipolar, the other bipolar; but evidence on this point is scanty and the matter is merely mentioned here. There is no doubt that bipolar cells enter into the group.

Hundreds of preparations have been seen in which each aesthetask-bearing joint of both antennae in each sex contained a group of cells as described above. Many cases have been carefully examined under high power, and without exception the conditions of the innervation of the sense organs are as described. Not all of the sense organs on the grasping antenna of the male

show such groups of cells related to them; but the joints which carry aesthetasks similar to those of the female antennae always contain the groups of ganglion cells.

It is worth noting that with one possible exception no case has been observed in which the so-called tactile bristles are innervated, nor has there been any indication that there are nerve cells standing in relation to them. All the ganglion or sensory cells that have stained with methylene blue are related only to the sense-clubs. Thus it does not appear that the tactile bristles on the anterior antennae are innervated as vom Rath claims for all sensory hairs.

Though the indications in my material are that the bristles on the antennae do not receive nerve fibres as an axial strand, there is good evidence that the furcal bristles of *Cyclops* contain nerve strands for a considerable portion of their length. This is shown especially well in cases where vom Rath's fluid was used as a fixing agent, followed by pyroligneous acid. Here the two longer and heavier bristles on each furcal ramus have an axial strand which is distinctly fibrillar in character. In the course of this strand there is a nucleus-like body, which may be distant half the length of the bristle from the base, or less. That these bodies are nuclear is strongly indicated by their reaction to haematoxylin. Pl. 2, fig. 11, is a drawing from such a preparation; the fibrillar nature of the core is slightly indicated even here, and is much more striking in vom Rath preparations. There may be more than one nucleus in the length of the axial strand though it is usual to find but one.

It may be well to note that Chun ('96, p. 92 and Pl. 5, fig. 5) found very comparable structures, which he called nerves, in the longer swimming bristles of Cirriped larvae; and to call attention to Kotte's (:03) claim for axial strands of nerve fibrillae in the highly developed setae of deep sea Euphausias. This is not the place to discuss the significance or character of the structure in *Cyclops;* indeed it would be difficult to do so. The appearance described occurs so regularly in tissues fixed and stained in different ways that it is hard to believe we are dealing with artefacts. It should be said that this structure has not been

seen in the furcal bristles of *Diaptomus*, but one should reserve a positive declaration that there is no such thing in that case.

It has been possible to detect a nerve supply for the rostral filaments of *Diaptomus* in my preparations with methylene blue (Pl. 2, figs. 12, 13, 14). The function of the filaments has been problematical though Claus looked upon them as protective organs. The presence of innervation would seem to indicate that they are sensory in function. I have seen in a good many cases that a nerve fibre passes from a ganglion cell to each prong of the rostrum, there to ramify much as in the case of aesthetasks of the antennae. In most cases I have seen but one such cell for each filament, and cannot give it its central connection, though it can be said with accuracy that there is one ganglion cell for each rostral filament. Figs. 12, 13, and 14 show the appearance in side view and fig. 14 gives the location of the cell well enough for our present purpose. In one case it was very clear that the peripheral processes of two ganglion cells united and then passed to one prong of the rostrum.

The structure of the central nervous system to be mentioned briefly is shown in Pl. 1, figs. 9, 10. This has been observed several times in both male and female animals. It will be seen in fig. 10 that the two cells located in the last segments of the abdomen give off anterior and posterior processes. The former unite and the single fibre thus formed has been traced forward as far as the level of the second maxilliped. Nothing more as to its structure or connections can be said at this time, though it is probable that it belongs in the category of fibres described by Richard ('91, p. 205, figured on Pl. 8, figs. 6, 7, or 31). What connection it has with the condition he shows in Pl. 7, fig. 4, I cannot say.

SUMMARY.

1. Each aesthetask-bearing joint of the anterior antennae of the male and female of *Diaptomus* contains a group of cells which stain with methylene blue. It can be seen that peripheral processes arise from such cells and unite into a single strand to enter the aesthetask.

2. The so-called tactile bristles on the antennae do not show such characters. But in the furcal bristles of a species of *Cyclops* structures have been found which are probably nervous in character.

3. The rostral prongs of *Diaptomus* are innervated in a manner similar to that of the aesthetasks. This would indicate the sensory function of the rostrum.

4. In several cases it has been seen that there are bipolar cells situated far back in the abdomen, the central processes of which unite before entering the thorax and pass as a single fibre far forward toward the brain.

Berkeley, California,
December 14, 1905.

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DESCRIPTION OF FIGURES.

Figs. 5, 6, 7, 8 (Pl. 1), and fig. 14 (Pl. 2), have been redrawn in black from drawings made in color from the preparations. The other figures as they stand were drawn with the camera. Figs. 9, 10, 14 are semi-diagrammatic in unimportant details. All but fig. 11 show the conditions in *Diaptomus*.

PLATE 1.

Fig. 1.—An aesthetask (*aes.*) with its group of ganglion cells (*n. c.*). The peripheral processes of the latter (*n. f. per.*) are shown entering the aesthetask as a single strand. × 1040. Methylal method.

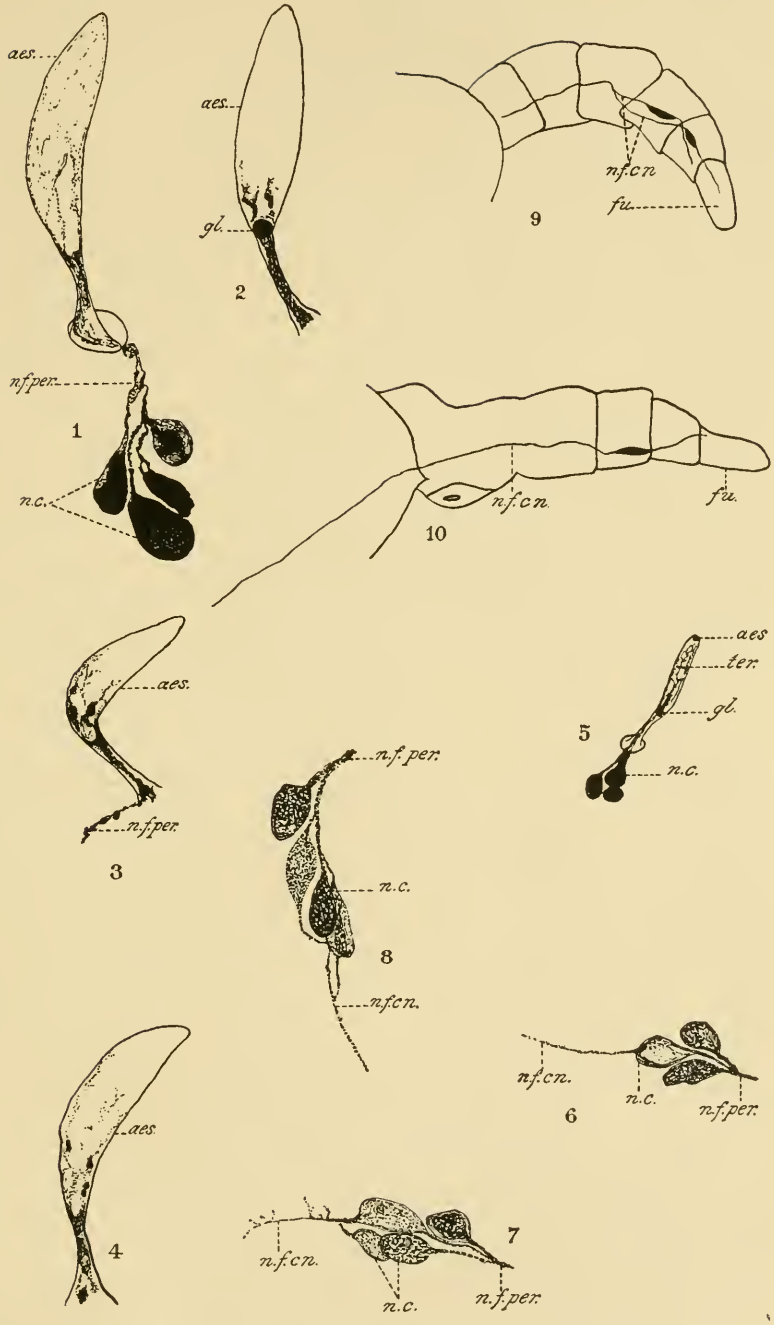
Figs. 2, 3, 4.—Aesthetasks (*aes.*) and peripheral nerve fibrils (*n. f. per.*). Fig. 2 shows the globule (*gl.*) which occurs pretty regularly. (Cf. fig. 5.) All figures, × 1000; preparations by the methylal method.

Fig. 5.—An aesthetask (*aes.*), drawn before the stain was fixed, showing the nerve termination (*ter.*) on the wall of the sense organ. The globule (*gl.*) near the base is characteristic. × 455. Methylene blue.

Figs. 6, 7, 8.—Drawings giving the appearance of various groups of nerve cells (*n. c.*), with their peripheral (*n. f. per.*) and central (*n. f. cn.*) fibrils. The depth of staining indicated is characteristic. All the figures, × 1000; corrosive sublimate alcohol method.

Fig. 9.—Abdomen of male, lateral, showing two nerve cells whose central processes after uniting pass far forward. (*Fu.*) furcal ramus. × 98; methylene blue without fixation.

Fig. 10.—Abdomen of female, lateral. The central fibre (*n. f. cn.*) could be traced as far forward as the second maxilliped. × 455; methylene blue without fixation.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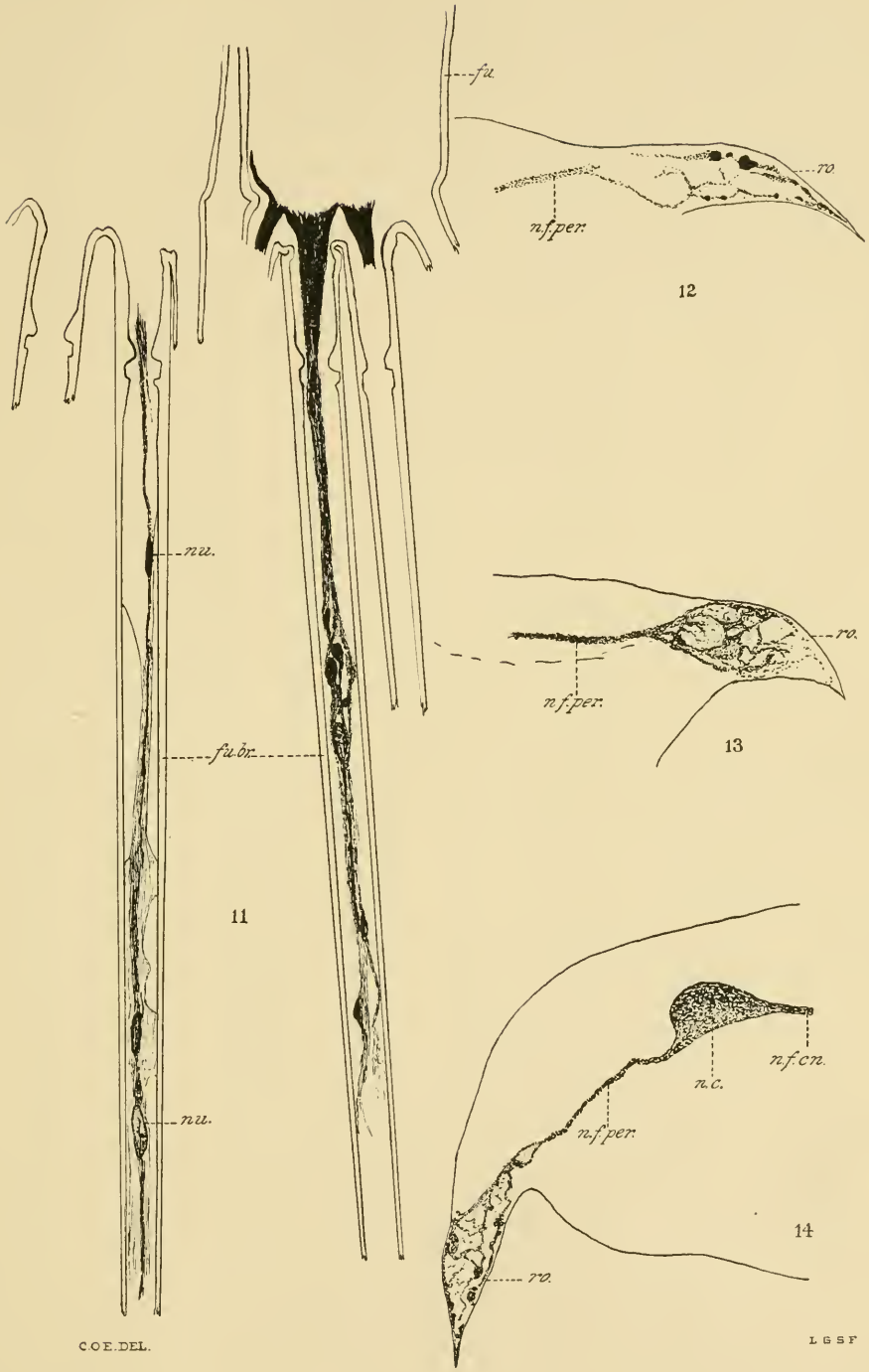
C.O.E.DEL.

PLATE 2.

Fig. 11.—A portion of the furca (*fu.*) and bristles (*fu. br.*) of a female *Cyclops albidus,* showing the nerve-like strand in the longer bristle and the nuclei (*nu.*) in the strand. × 365; Zenker fixation, stained in haematoxylin.

Figs. 12, 13, 14.—Rostral prongs (*ro.*) seen in lateral view, showing the nerve fibrils (*n. f. per.*) passing to them. Fig. 14 shows the nerve cell (*n. c.*) from which the fibres arise. (*n. f. cn.*), central nerve fibres. All the figures, × 800. Fig 12 from a preparation by the corrosive sublimate alcohol method. Figs. 13, 14 from methylal preparations.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IX

OSTRACODA OF THE SAN DIEGO REGION

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MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

IX.

OSTRACODA OF THE SAN DIEGO REGION.

I.—HALOCYPRIDAE.

BY

CHANCEY JUDAY.

INTRODUCTION.

The material for the following paper was obtained from plankton collections which were made during the progress of the work carried on by the Laboratory of the Marine Biological Association of San Diego. About a thousand catches were obtained between June 20, 1901 and July 20, 1905, most of them being made between July 1, 1903 and the latter date. About a hundred of the earlier catches were made in the vicinity of San Pedro, California, and the remainder in the region of San Diego. Ostracoda were found in only 128 out of the total number of catches. Only one of the catches reached a depth of more than 210 fathoms. This single haul was made from a depth of 400 fathoms and proved to be the richest, not only in the number of individuals obtained, but also in the number of species represented.

The present report includes only the pelagic forms, the littoral forms being reserved for a future report, as comparatively little of the collecting was done in the littoral region. The pelagic Ostracoda belong to three genera and ten species, one of the latter being new.

KEY TO GENERA AND SPECIES.

A. Shell more or less elongated; rostral process well developed.

B. Basal join of secondary branch of antenna without mammillary process; chewing pad of mandible without distinct setae and spinous teeth ..... Genus *Archiconchoecia*
A. striata

BB. Basal joint of secondary branch of antenna with a mammillary process; chewing pad of mandible possessing setae and teeth ..... Genus *Conchoecia*

C. Without a conspicuous spine at postero-dorsal angle.

D. Shell longer than 2 mm.

E. Postero-dorsal angle prominent, smaller than a right angle ..... *C. pacifica*

EE. Postero-dorsal angle obtuse, greater than a right angle.

F. Hooked appendage of secondary branch of right male antenna with two abrupt bends ..... *C. magna*

FF. Hooked appendage with only one abrupt bend ..... *C. hyalophyllum*

DD. Shell less than 2 mm. in length.

E. One or more of the sensory filaments of the antennule furcate ..... *C. clausi*

EE. None of the sensory filaments of antennule furcate ..... *C. spinirostris*

CC. Shell with a more or less conspicuous spine at postero-dorsal angle.

D. With a blunt projection at postero-ventral angle ..... *C. ritteri*

DD. Without a blunt process at postero-ventral angle.

E. Shell very much elongated and narrow, three to five times as long as high..... *C. daphnoides*

EE. Shell not greatly elongated, about twice as long as high ..... *C. mülleri*

AA. Shell almost as high as long; rostral process short and inconspicuous, furnished with a hinge process ..... Genus *Halocypris*
H. pelagica

Family HALOCYPRIDAE.

Valves sub-equal, very thin and flexible, composed of two tunics which are scarcely adherent except at the edges; hinge margin straight, almost or entirely toothless; antero-dorsal extremity produced into a more or less prominent rostrum or beak with a subjacent rostral sinus. Eyes wanting, or present only in an abnormal condition. A frontal organ, or tentacle which usually has a club-shaped extremity or capitulum, projects forward in the median line between the antennules. The antennules are unlike in the two sexes; in the female, weak, indistinctly jointed, immobile, and bearing a fascicle of sensory setae; in the male, larger, more distinctly jointed, mobile and bearing a long seta. Antennae natatory, bearing a secondary branch which has a prehensile appendage. Mandibles well developed, biting plate dilated and toothed at the apex; mandibular palp large, four-jointed, the basal joint with a large dentated lobe which is in contact with the biting apex of the mandible; terminal joints bearing setae or spines. Second pair of feet larger than the others and unlike in the two sexes; third pair very small. Caudal laminae short and clawed on the posterior margin. Copulatory organ of the male single, sinistral.

Genus **Archiconchoecia** Müller.

Shell with a well developed rostrum which is similarly shaped in both sexes. Groups of glands open almost symmetrically on the two halves of the shell, somewhat below the postero-dorsal angle. Antennules in both sexes very similar, in the male somewhat stronger, only indistinctly jointed; first and second joints fused together; with six sensory filaments at the end, of which four belong to the ultimate and two to the penultimate joint. Secondary branch of the antennae without mammillary process; the five long setae of the last two joints similar to each other, all sensory. Chewing part of mandible without distinct setae and spinous teeth, armed only with minute spinules. First foot similar in both species, stronger in the male, but without any marked differences in the setae of the last joint. Branchial plate

as in *Conchœcia* with three groups of respiratory filaments. Second foot with two setae directed backward and upward. Furca with six spines.

1. **Archiconchoecia striata** Müller.

Pl. III, figs. 1-3.

1894. *Archiconchoecia striata* Müller, G. W., p. 225, pl. VI, figs. 31-46, 49, and pl. VIII, fig. 34.

Shell rather short and compressed, ratio of height to length varying between 1:1.6 and 1:1.75; greatest height about two-thirds of the way back; posterior to this point the ventral margin bends upward rather strongly, but anteriorly it bends upward more gradually. The posterior margin forms an arch whose highest point lies about a third of the distance down from the dorsal margin; near this point, rather widely removed from the posterior end of the dorsal margin, lie the openings of the glands, almost but not quite symmetrical on the two halves of the shell. Rostrum short, but distinct, pointed. Surface of the shell striated, the striae being especially distinct on the anterior half where they run parallel to the dorsal and anterior margins; they are connected by anastomoses. About the middle of the ventral margin, near the edge, is situated a circumscribed spot which is not equally distinct in all individuals, but which is especially distinct in stained shells. Frontal organ straight in both sexes, with a blunt end which possesses a small process in the male; in the male longer, in the female shorter than the antennule. Antennule indistinctly jointed in both sexes, tolerably short, somewhat longer in the male than in the female; the six sensory setae are of equal length, about one and a half times as long as the antennule. Secondary branch of antenna with five sensory filaments which are almost equal in length and similar in shape; a few small papillae on lower part of first joint; the hook is strong. Spines of the furca slender, the first longer and stronger than the second. Upper lip with paired folds at its anterior edge and a long gland which extends up to the base of the antennule. Living animal yellowish, especially in the anterior half and along the ventral margin.

Length: female 0.64; male 0.62 mm.

Distribution. Gulf of Naples (Müller); Pacific Ocean off San Diego, California.

Genus **Conchoecia** Dana.

The bivalved shell which completely covers the animal is elongated, subquadrangular, sometimes smooth, but usually ornamented with a striated or reticulated sculpture either toward the margins or over the whole surface; rostrum and rostral sinus well developed; hinge process absent or only feebly developed. Antennules of the male distinctly four-jointed; the second joint bears a seta which lies ring-like around the frontal organ; the third bears a sensory filament and an elongated seta; the fourth joint bears one sensory filament and two elongated setae. In the female, the antennules are only indistinctly jointed, slender, and bear four sensory filaments and one long, slender seta.

Antennae greatly developed; the basal joint is large, ham-shaped, and bears a natatory branch at its apex which usually consists of eight joints of which the first is long and cylindrical, the rest short and somewhat quadrate; each of the short joints bears a long natatory seta, but the last one has more than one. The secondary branch arises on the ventral edge of the basal joint of the primary branch; it consists of three joints; in the male the basal joint forms a flattened expansion, the second is short and cylindrical, the third, which is lateral to the second, is falcate; the second joint bears two long setae, and the third three sensory filaments; in the female, the second and third joints are fused and bear a lash of filaments.

The basal joint of the mandible has a strong masticatory lobe and a four-jointed palp whose first joint likewise has a masticatory lobe. The maxilla consists of a two-jointed stem, with three masticatory lobes and a three-jointed palp. A second maxilla is wanting.

The basal joint of the first pair of feet, sometimes called the maxillary feet, bears a circular respiratory plate on the hinder edge and a four-jointed branch directed backward. The second pair of feet is five-jointed; in the female directed downwards;

much stronger in the male and ending in three long, curved, plumose setae; in both sexes the basal joint bears a respiratory plate. Last pair of feet short, indistinctly jointed, and bearing two terminal setae, one of which is very long, the other short.

The furca consists of two laminae pressed together, each of which bears a series of curved spines or ungues on the posterior margin and a single long, slender spine on the anterior margin. Copulatory organ of the male single and situated on the left side.

1. **Conchoecia spinirostris** Claus.

Pl. III, figs. 4-7.

1874. *Conchœcia spinirostris*, Claus, p. 6, pl. I, figs. 1, 6a, 8; pl. II, figs. 11, 14, 15.
1887. *Conchœcia pellucida*, Sars, p. 80, pl. XI, figs. 1-4; pl. XII; Pl. XIII, figs. 1-4.
1891. *Conchœcia spinirostris*, Claus, p. 56, pl. I, figs. 1-12.
1894. *Conchœcia spinirostris*, Müller, G. W., p. 227, pl. VI, figs. 1-9, 13.
1896. *Conchœcia spinirostris*, Brady and Norman, p. 689, pl. LX, fig. 22.

Shell pellucid, about twice as long as high, with longitudinal markings which are very obscure in preserved specimens; oblong, higher behind than in front in the female; in the male the dorsal and ventral margins are nearly parallel and the posterior margin is straight. Frontal organ of female straight, without a distinctly separated capitulum; shape of outer portion somewhat variable, usually slightly enlarged towards the end; sometimes ending bluntly, sometimes in a sharp-pointed projection; in male angularly bent, with a club-shaped capitulum which has a blunt end and a very few minute hairs on the basal half.

Antennule of female indistinctly jointed, rather short, without dorsal seta on second joint; sensory setae about half as long as principal seta which is curved and bears small hairs on the dorsal margin of the basal third, and on the ventral margin of the middle third; principal seta of male antennule scarcely longer than the adjacent ones, armed with backward directed hooks; the distal eleven or twelve pairs of hooks large, strong, and closely set, followed proximally by ten or twelve much smaller ones which are farther apart; long sensory filament curved backward in opposition to the antennule.

The longer of the two setae on the basal joint of the secondary branch of the female antenna armed with fine, short hairs, and in the male bearing two long hair-like processes; in the female four of the five setae of the last two joints nearly equal in length, the fifth a little longer. Hooked appendage of secondary branch of right male antenna strongly angulated near base and again broadly curved towards distal end; that of left side with only a bend near the base.

The spines of the caudal laminae curved only towards the points; the last four very small.

Length: female 1.1–1.4; male 1.0–1.1; height 0.55–0.66 mm.

Distribution. Mediterranean (Claus); Adriatic, Gulf of Naples (Müller); Pacific Ocean off San Diego, California.

2. **Conchoecia magna** Claus.

Pl. III, figs. 8-11; pl. IV, figs. 1, 2.

1874. *Conchœcia magna,* Claus, p. 6, pl. I, fig. 6c; pl. II, figs. 16, 18.
1887. *Conchœcia tetragona,* Sars, p. 82, pl. XI, figs. 5, 6; pl. XIII, figs. 5-9.
1890. *Conchœcia tetragona,* Müller, G. W., p. 274, pl. XXVIII, figs. 28, 29, 33, 34, 39, 40.
1891. *Conchœcia magna,* Claus, p. 57, pl. II; pl. III, figs. 1, 2.
1894. *Conchœcia magna,* Müller, G. W., p. 228, pl. V, figs. 7-12, 16-22, 27-31, 35-39, 45-52.
1896. *Conchœcia magna,* Brady and Norman, p. 687, pl. LXII, figs. 5-13.

Shell elongated, subquadrangular, slightly higher behind than in front; length about twice the height; dorsal margin with depression near the middle; anterior margin evenly curved, rounding off gradually into the ventral margin; the latter slightly sinuous in the middle and posteriorly curved over rather abruptly into the posterior margin; postero-dorsal angle obtuse; in the male the rostrum is stout and blunt, while in the female it is slenderer and bent downward more strongly. The striations of the shell are very obscure, most of them running parallel to the dorsal and ventral margins; posteriorly two or three striae run parallel to the posterior margin, and anteriorly below the rostral sinus they run parallel to the curved antero-ventral margin; anteriorly some of the striae branch and anastomose.

In the male the capitulum of the frontal organ is more or less truncated at the base and has a blunt apex; hispid with minute hairs; the three chief setae of the antennule almost equal in length, the principal one bearing beyond its middle about twenty pairs of small recurved hooks. The hooked appendage of the secondary branch of the right antenna is bent at almost a right angle near the base and beyond this is again bent abruptly, forming an arch; the end is rather sharp-pointed, with a few crenulations on the inner margin; the appendage of the left side is much smaller, abruptly bent near the base, but is not bent a second time; it also ends in a rather sharp point which is crenulated on the inner margin. The principal spine on the basal joints of both secondary branches bears three pairs of long hair-like processes.

In the female the capitulum of the frontal organ is somewhat larger than the peduncle; it is bent downward, has a sharp pointed apex, and is hispid with a few marginal hairs. The three sensory setae of the secondary branch of the antenna about equal in length, nearly two-thirds as long as the principal seta.

Length: male 2.4; female 2.6 mm.

Distribution. Widely distributed at the surface and in the depths of the Mediterranean Sea and Atlantic Ocean (Claus); Pacific Ocean in the San Diego region.

3. **Conchoecia hyalophyllum** Claus.

Pl. IV, figs. 3, 4.

1891. *Conchœcia hyalophyllum*, Claus, p. 60, pl. VI, figs. 2-10; pl. VIII, fig. 9.

1896. *Conchœcia hyalophyllum*, Brady and Norman, p. 692.

Female.—Shell rather short, about one and a half times as long as greatest height; nearly quadrangular, a little higher behind than in front; thin, pellucid, much compressed laterally; rostrum fairly large and rather strongly curved.

Frontal organ slender, elongated, with very long, angularly bent, sharp pointed extremity or capitulum which bears on its upper margin a few spine-like hairs and on its under side two rows of the same.

The antennule bears a long, curved terminal seta and four sensory ones, the former about two and a half times as long as the latter; the long seta is armed with some spinules on its ventral margin in the middle third. The principal seta of the secondary branch of the antenna is about a fourth longer than the longest of the four adjacent setae.

Length 2.4; greatest height 1.4 mm.

Male.—Capitulum of frontal organ shorter than in female, broadly club-shaped, irregularly armed with spinous hairs; terminal seta of antennule bearing about twenty pairs of slender, thickly set spines, and not longer than the two neighboring setae; proximal sensory seta thick and very long, almost as long as the antenna; hooked appendage of secondary branch of right antenna bent into a right angle at the base.

Length: one male was obtained which measured 2.9 mm.

Distribution: Ischia, Orotava, and Atlantic Ocean, lat. 34° 18′ N., long. 15° 34′ W. (Claus); Pacific Ocean off San Diego, California.

4. **Conchoecia pacifica** nov. nom.

Pl. IV, figs. 5-7; pl. V, figs. 1,2.

1890. *Conchœcia oblonga*, Müller, G. W., p. 272, pl. XXVIII, figs. 26, 31, 32, 36, 37.

Shell elongated, a little more than twice as long as high; somewhat higher behind than in front; postero-dorsal angle acute, with a blunt point which is a little larger on the right valve than on the left. Shell sculpture limited to a pair of striae near the ventral and posterior margins which run parallel to the margins; these striae scarcely noticeable in the female, more distinct in the male. Rostrum prominent, bent downward; rostral sinus rather narrow and deep.

In the male the outside of the shell bears a number of hair-like processes, some of which are tolerably long; a row of about six or eight of these on either valve a short distance in front of the posterior margin. These hair-like processes are fewer and shorter on the shell of the female.

In the male the shell has a reddish-orange color in the following regions: Edges of valves from anterior margin of hinge

along rostrum, anterior margin, and anterior two-thirds of ventral margin; a small oval spot along dorsal margin near the postero-dorsal angle; a quadrangular patch over the large muscle of the antenna; a narrow band extending from hinder edge of rostral sinus posteriorly and dorsally to anterior edge of hinge. In the female only the anterior margins of the valves are sometimes tinged with orange.

Male.—The capitulum of the frontal organ is dilated and somewhat truncated at the base, with a blunt apex; hispid with a few short hairs. The antennule bears three long setae, the first of them is a little longer than the other two and bears in its middle third about forty pairs of very small recurved spines; the third seta bears a very small lamina just beyond its middle; there are two sensory setae, one of which is short, the other is much longer, is dilated near the base, and turned back in opposition to the antennule. The hooked appendage of the secondary branch of the right antenna is bent at an acute angle near the base; the outer end is distinctly crenulated on the inner margin; the left appendage is somewhat smaller and not so distinctly crenulated at the end.

In both sexes the secondary branch of the antenna bears a sensory seta on the last joint with an enlarged basal portion where the walls are rather thick and strong, while the outer portion is thin-walled and weak, and ends in a sharp point.

In the female the frontal organ is straight; sometimes the capitulum is more or less distinctly separated from the peduncle by a constriction; hispid with sparsely set minute hairs.

Length: male 2.4; female 3.1 mm.; height of female 1.2 mm.

Distribution. West coast of South America between Caldra and Antofagasta, 25° S. lat., 72° W. long. (G. W. Müller); off San Diego, California.

The name given to this species by Müller (*C. oblonga*) was previously applied to another species of *Conchœcia* (*Paraconchœcia oblonga*) by Claus, so the name *pacifica* is proposed in its stead.

5. **Conchoecia clausi** (Sars).

Pl. V, figs. 3, 4.

1887. *Halocypris clausii*, Sars, p. 87, pl. XI, figs. 7-10; pl. XIV, figs. 6-18.
1891. *Microconchœcia clausii*, Claus, p. 73, pl. XX.
1894. *Conchœcia clausii*, Müller, G. W., p. 230, pl. VI, figs. 21, 23-30; pl. VIII, figs. 31, 32.
1896. *Microconchœcia clausii*, Brady and Norman, p. 700, pl. LXIII, figs. 3-9.

Shell of female short and high; dorsal margin only slightly depressed near the middle; ventral evenly and broadly convex, forming a continuous curve with the anterior and posterior margins; postero-dorsal angle wide, greater than a right angle; rostrum rather large and curved downward; rostral sinus of moderate size; in the male the shell is slightly narrower. In both sexes the valves are rather thickly and strongly reticulated; striae well developed over nearly all the surface except at the posterior edge in the female.

Frontal tentacle of female short, scarcely reaching beyond extremity of antennule; nearly straight, slightly club-shaped, but with no distinct capitulum; end blunt and rounded; that of the male much longer than the antennule; capitulum curved, spoon-like, dilated at the base, without hairs. Antennules of the female rather small, indistinctly jointed, bearing four sensory setae, the three posterior of which are furcate, and a long, curved terminal seta; those of the male larger, distinctly five-jointed; bearing two sensory setae, the proximal one of which is rather long and furcate, the other short and simple; of the three long setae the distal one bears about eight small button-like nodules which are set in a single row on its inner margin.

Hooked appendage of the secondary branch of male antenna strongly bent, thickened toward the base; outer end indistinctly crenulated on its inner margin; in the female the secondary branch of the antenna bears four setae nearly equal in length and a fifth about a half longer.

Length: female 0.72–0.74; male 0.75–0.8 mm.

Height, female 0.55 mm.

Distribution. Capri, Las Palmas, Funchal (Claus); Messina (Sars); Naples (Norman and Müller); San Diego, California.

6. **Conchoecia mülleri** nov. nom.

Pl. V, figs. 5-7; pl. VI, figs. 1-5.

1890. *Conchœcia striata*, Müller, p. 270, pl. XXVIII, figs. 12-18.

Shell rather thin but firm; transparent, with distinct longitudinal striae and a few small irregular markings along the posterior margin; shell of female somewhat higher behind than in front, twice as long as greatest height; that of male about as high in front as behind, a little more than twice as long as high; in both sexes the dorsal margin is nearly straight, with a depression near the middle; each valve with a short, strong, spinous projection at the postero-dorsal angle; anterior margin broadly rounded, passing over gradually into the ventral margin; postero-ventral curvature more abrupt; rostrum broad, with a blunt apex; rostral sinus wide and rather shallow.

Capitulum of frontal organ of male dilated and truncated at the base, with a blunt apex; posterior two-thirds hispid with sparsely set hairs; capitulum of female similar but not dilated so much nor so distinctly truncated at the base and a little more pointed at the apex.

The first seta of the male antennule is longer than the other two, and bears in the middle about twenty pairs of short, stout, recurved spines; the third or posterior seta is slightly curved a little beyond the middle and bears at this place a small lamina which has a rough edge; beyond this lamina, on the opposite side of the seta, are some minute spinules pointing forward. One of the sensory setae is short, the other is curved at the base and turned backward in opposition to the antennule. The antennule of the female bears one long seta and four sensory ones which are less than half as long.

The hooked appendage of the secondary branch of the male antenna is strongly but regularly curved, forming a rather narrow arch; the outer end is dilated and bears a small, blunt, tooth-like process. The mammillary process is blunt in the male but sharper pointed in the female. In the male the basal portion of the third sensory seta of the secondary branch is slightly enlarged and bears minute hairs; each of the three sensory setae of the

female has a slightly enlarged portion near the base which bears minute hairs.

The ungues are distinctly pectinated.

Length: female 2.8; male 2.6 mm.

Distribution. West coast of South America between Caldra and Antofagasta (Müller); a few specimens were found in the plankton collections made off the coast of southern California in the vicinity of San Pedro and San Diego.

The specific name, *striata*, applied to this species by Müller was previously used by Claus for another species of *Conchœcia*, so I have taken the liberty of substituting Dr. Müller's own name instead.

7. **Conchoecia ritteri** nov. sp.

Pl. VI, figs. 6-8; pl. VII, figs. 1, 2.

Shell of female elongated, lower in front than behind, greatest height a little less than half the length; sub-quadrate in outline when seen from the side; dorsal margin depressed near the middle; anterior margin rather strongly curved; ventral margin sinuous, protuberant posteriorly; posterior margin sloping backward a little so that it forms a more acute angle with the dorsal than with the ventral margin; a conspicuous spine at the postero-dorsal angle, that of the right valve being only about a third as long as that of the left; postero-ventral angle with a short, blunt, rounded process; rostrum rather long, pointed, and directed forward; rostral process of left valve longer than that of the right; rostral sinus wide and comparatively shallow.

Entire shell distinctly reticulated; dorsally the sculpture markings consist of striae, for the most part longitudinal, which are broken up into small square or rectangular areas; anteriorly below the rostral sinus and along the ventral margin the sculpture markings are more or less irregular in shape.

Frontal tentacle of female long, rather stout, and somewhat club-shaped; capitulum long and not very distinctly separated from the stalk, bearing a few rather long slender marginal hairs posteriorly. Antennule with one long curved seta and four short sensory ones. Secondary branch of antenna with two long setae

and three shorter, sensory filaments: the basal third of the sensory filaments is armed with a few minute hairs; mammillary process rather large and blunt. The first unguis is slender and not pectinate: the others gradually increase in length and are strongly pectinate.

Length of female, 5.1 mm.

The male of this species is unknown. Four females were obtained in a 400-fathom plankton catch which was made about half way between San Diego, California, and San Clemente Island.

I take great pleasure in naming the species for Dr. William E. Ritter, Director of the San Diego Marine Biological Station.

8. **Conchoecia daphnoides** (Claus).

Pl. VII, fig. 3.

1891. *Conchœcilla daphnoides*, Claus, p. 68, pl. XV.
1896. *Conchœcilla daphnoides*, Brady and Norman, p. 697, pl. LXIV, fig. 22.
1896. *Conchœcilla lacerta*, Brady and Norman, p. 697, pl. LXII, figs. 1-4; LXV, figs. 1-10.
1901. *Conchœcia daphnoides* Müller, G. W., p. VII 6, figs. 11-14.

Shell very much elongated, in the female about five, in the male about three times as long as high. In the female the rostral process is unusually long and slender, the left noticeably longer than the right. The posterior part of the shell is produced into a long spine-like process, which in the female constitutes about a fifth and in the male about a fourth of the length of the shell; its lower margin passes over with a convex line into the distinctly arched ventral margin; each valve of the process bears a series of marginal spinules. On the right valve below the rostral sinus is a small projection on which there is a gland opening. Shell distinctly striated, but the course of the striae varies.

Frontal organ of the female straight, the capitulum rather distinctly separated from the peduncle; dilated and armed with fine hairs on its ventral margin. The principal seta of the antennule of the male is armed with long, slender spines which are very thickly set and directed backward; they extend proximally as far as the outer ends of the neighboring sensory setae. Both the right and the left hook-shaped end joints of the secondary

branch of the male antenna bent at a sharp angle, forming a proximal and a distal portion; distal portion almost straight, the right somewhat longer than the left.

Length: female 4.6; male 2.2–3.0 mm.

Distribution. Rather widely distributed in the Atlantic Ocean ranging from 60° 31′ N. lat. to 37° S. lat. Only one specimen of this species, a female, was found. It was obtained in a 400-fathom catch which was made about half way between San Diego, California, and San Clemente Island.

Genus **Halocypris** Dana.

Rostral process of the shell short, inconspicuous, with a joint which consists of a tooth on the left valve and a socket on the right. Rostral sinus very small. Hinge at posterior end of dorsal margin scarcely developed. Free edge of valves strongly rounded and thickly set with long gland cells. Frontal organ alike in both sexes; capitulum club-shaped. Basal joint of secondary branch of antenna without a mammillary process; principal seta of secondary branch strong, dilated and lancet-shaped at the end. Mandible without a crenulated pad and accessory teeth, but having a broad conical process directed toward the apex of the limb; a low ridge approaches the base of this process on one side.

9. **Halocypris pelagica** Claus.

Pl. VII, figs. 4-7.

1890. *Halocypris pelagica*, Claus, p. 25.
1890. *Halocypris dubia*, Müller, G. W., p. 269, pl. XXVIII, figs. 19, 23, 24, 30, 35; var. *minor*.
1891. *Halocypris pelagica*, Claus, p. 78, pl. XXI, figs. 1-11.

Shell short, ventricose, scarcely longer than high; length 1.1–1.4; height 0.9–1.1 mm.

Frontal organ rather thick and short; capitulum relatively short and scarcely bent. Antennule strongly curved, with two rectangular bends; terminal seta much longer than the four sensory ones, and armed with a few minute spinules just beyond the middle. Peduncle of the natatory branch of the antenna about twice as long as the short-jointed distal portion which bears long

plumose setae; principal seta of the secondary branch greatly dilated toward its distal end and about a third longer than the next seta, which is, in turn, nearly double the length of the remaining three; hooked appendage of male bent upon itself abruptly at the base, with the inner side of the extremity crenulated.

Distribution. Claus states that this form appears to be widely distributed in the Atlantic Ocean at the surface as well as at various depths; Pacific Ocean off San Diego, California.

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PLATE III.

Figs. 1-3. *Archiconchœcia striata.*

1. Shell of male. × 94.
2. Frontal organ of male. × 360.
3. Secondary branch of male antenna. × 360.

Figs. 4-7. *Conchœcia spinirostris.*

4. Shell of female. × 51.
5. Antennule of male. × 210.
6. Frontal organ of male. × 210.
7. Secondary branch of right male antenna. × 210.

Figs. 8-11. *Conchœcia magna.*

8. Shell markings showing branching and anastomosing of striae. × 150.
9. Frontal organ of female. × 85.
10. Secondary branch of right male antenna. × 145.
11. Secondary branch of left male antenna. × 145.

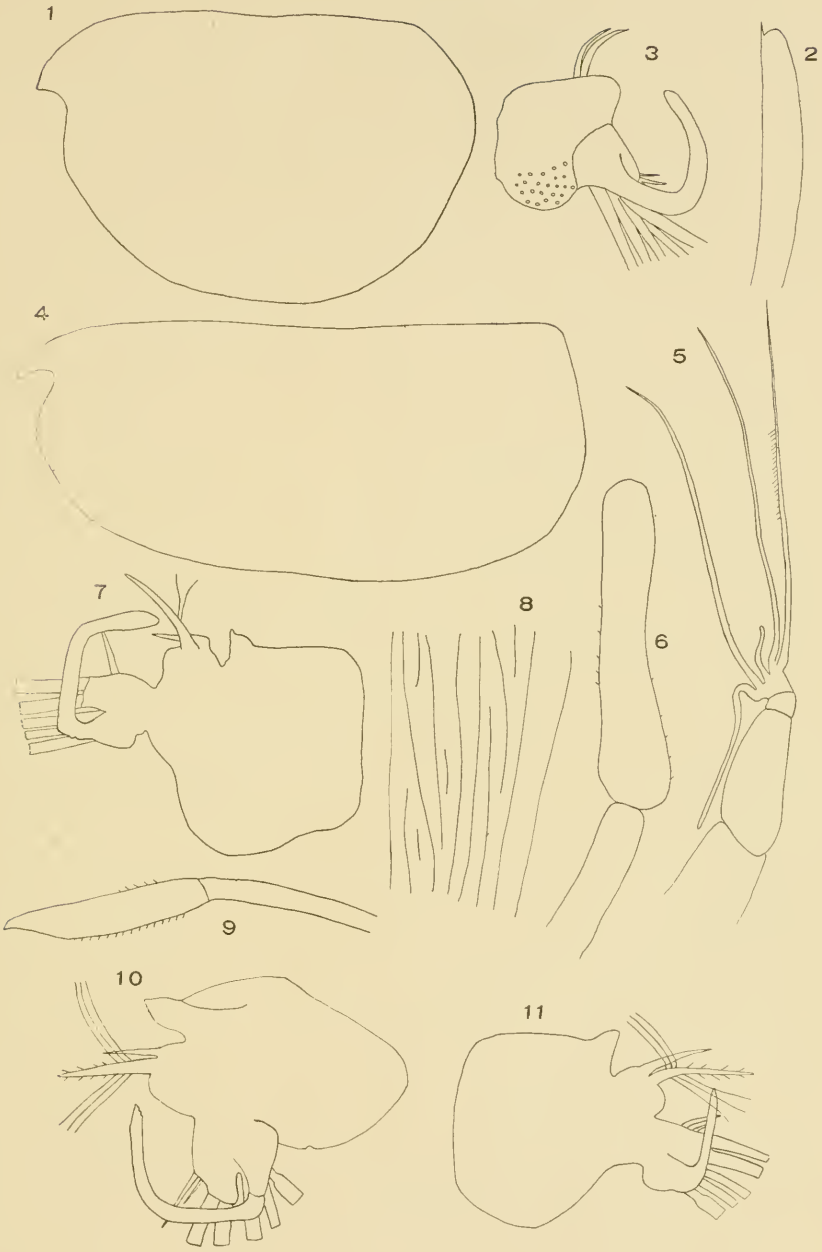
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PLATE IV.

Figs. 1, 2. *Conchœcia magna.*

1. Shell of male. × 38.
2. Claudal lamina and male organ. × 73.

Figs. 3, 4. *Conchœcia hyalophyllum.*

3. Shell of female. × 40.
4. Antennule and frontal organ of female. × 73.

Figs. 5-7. *Conchœcia pacifica.*

5. Frontal organ of female. × 73.
6. Frontal organ of male. × 82.
7. Secondary branch of right male antenna. × 112.

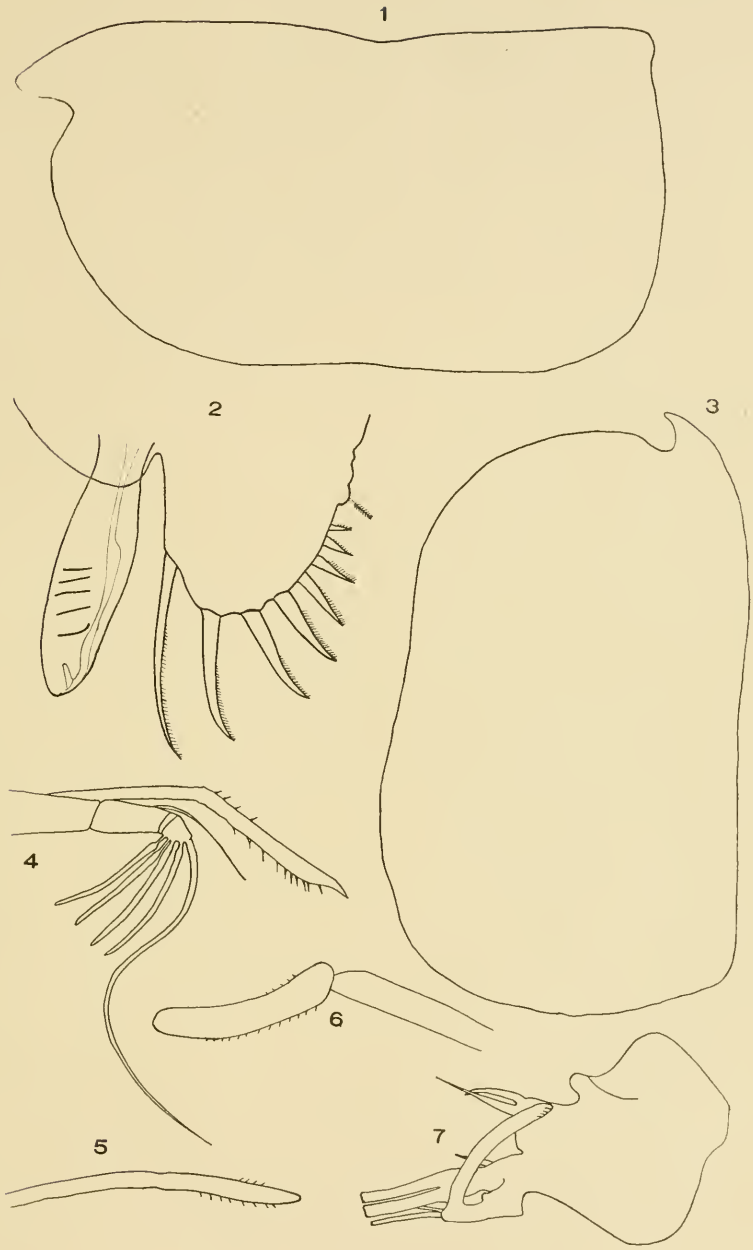
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PLATE V.

Figs. 1, 2. *Conchæcia pacifica.*

1. Shell of male. × 36.
2. Shell of male, ventral view. × 36.

Figs. 3, 4. *Conchæcia clausii.*

3. Shell of female. × 85.
4. Antennule and frontal organ of female. × 142.

Figs. 5-7. *Conchæcia müllerí.*

5. Antennule and frontal organ of male. 28.
6. Frontal organ of female. × 72.
7. Laminated portion of third seta of male antennule. × 390.

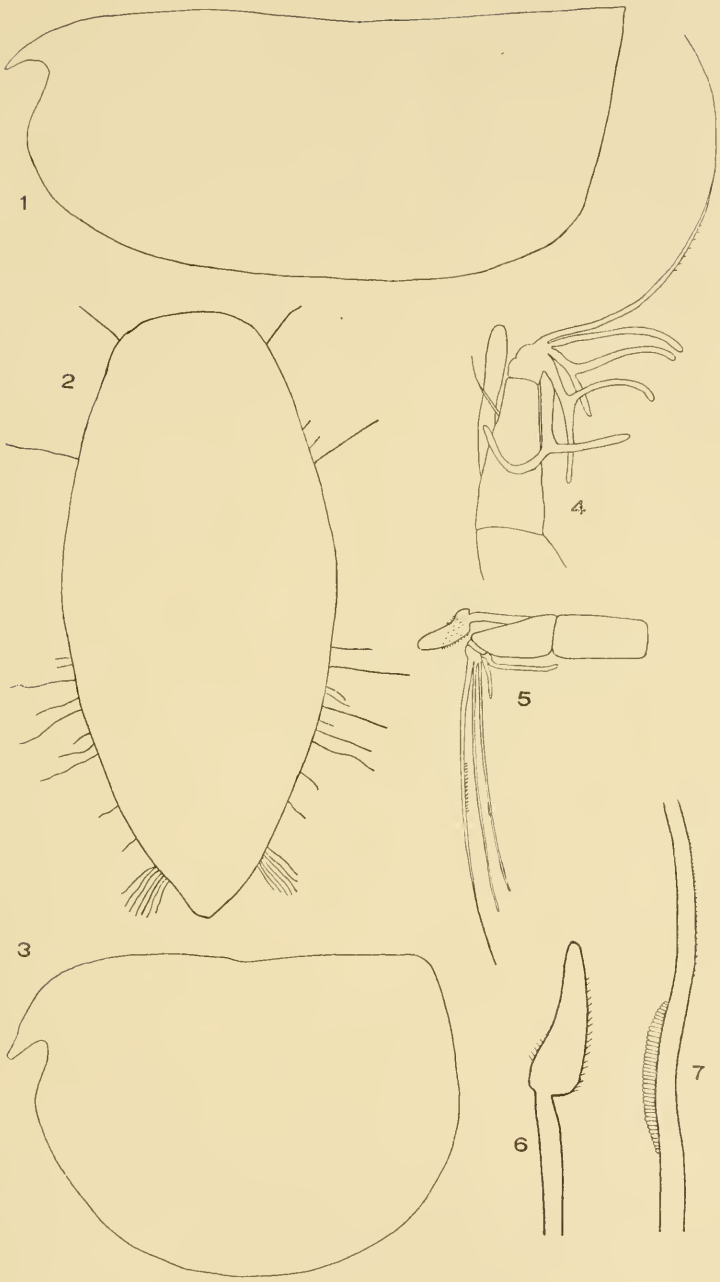
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PLATE VI.

Figs. 1-5. *Conchœcia mülleri.*

1. Shell of female. × 28.
2. Secondary branch of right male antenna. × 72.
3. End of hooked appendage of secondary branch of right male antenna. × 365.
4. Secondary branch of left female antenna. × 72.
5. Caudal lamina and male organ. × 72.

Figs. 6-8. *Conchœcia ritteri,* female.

6. Shell in side view. × 18.
7. Shell markings near antero-ventral angle. × 46.
8. Frontal organ. × 50.

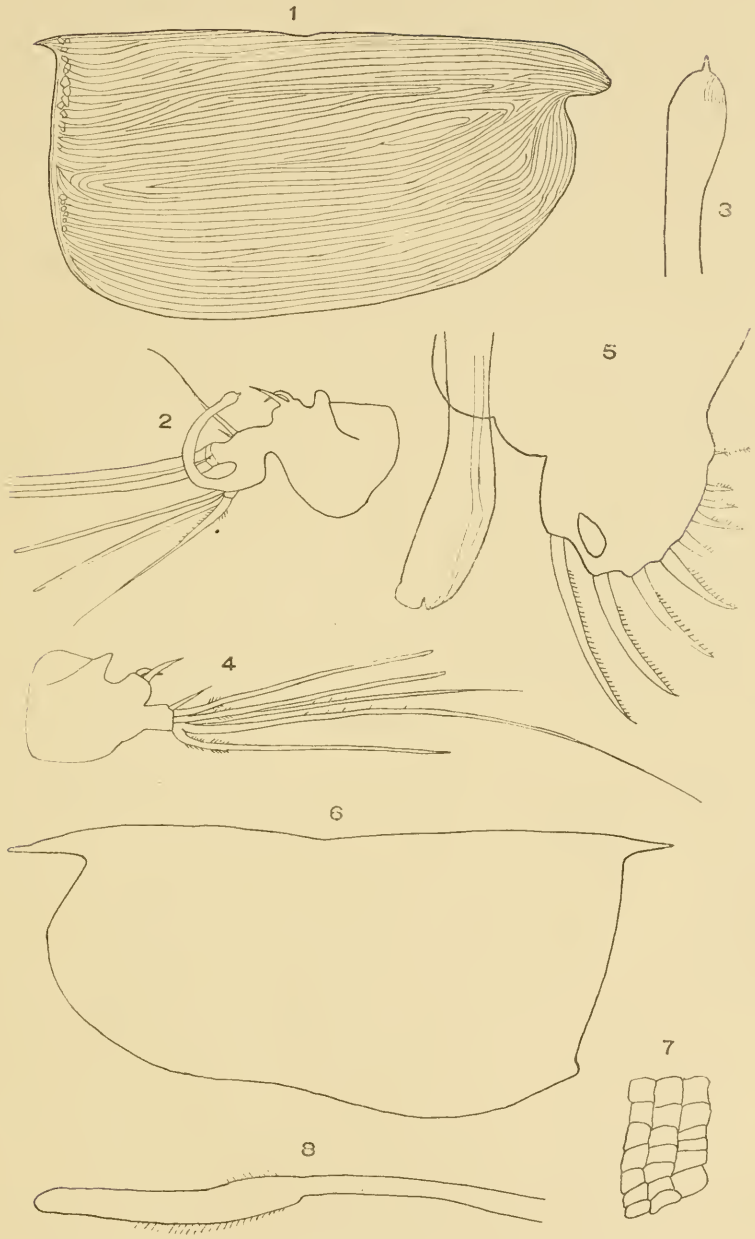
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PLATE VII.

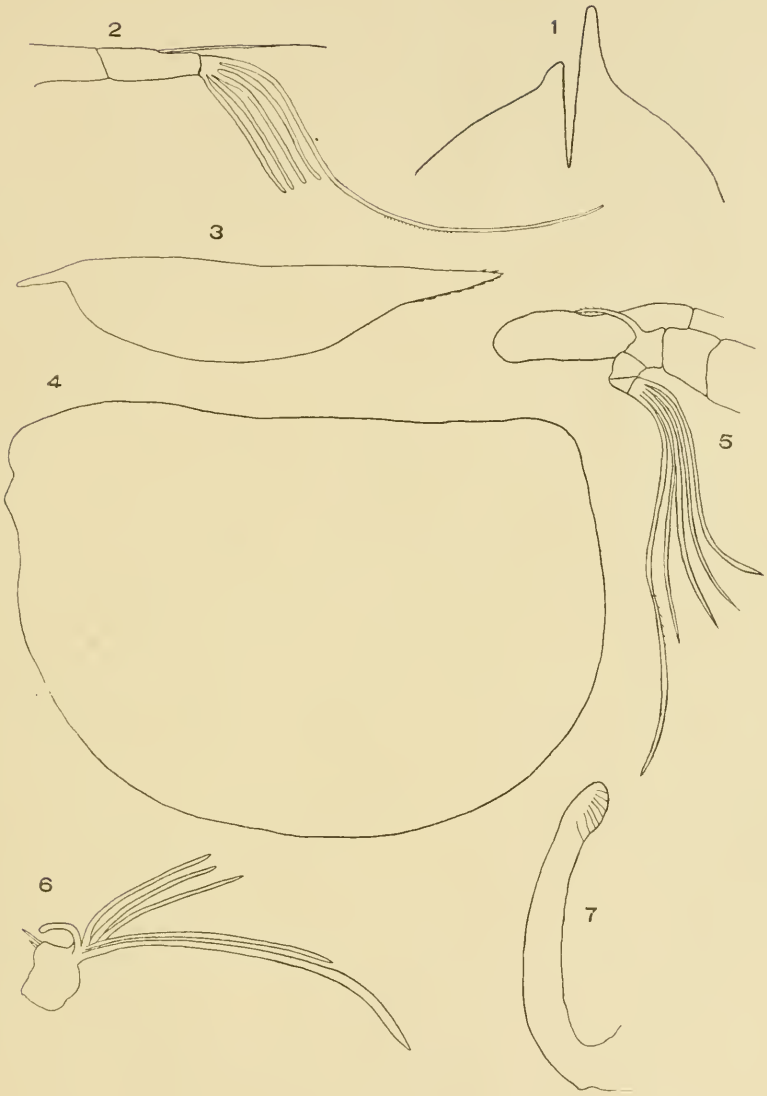
Figs. 1, 2. *Conchœcia ritteri*, female.

1. Ventral view of rostrum. × 50.
2. Antennule. × 35.

Fig. 3. Shell of *Conchœcia daphnoides*. × 21.

Figs. 4-7. *Halocypris pelagica*.

4. Right valve from within. × 65.
5. Frontal organ and antennule of male. × 72.
6. Secondary branch of left male antenna. × 72.
7. Hooked appendage of secondary branch of right male antenna. × 362.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ZOOLOGY
Vol. 3, Nos. 3 and 4, pp. 41-52, Pl. 8, Text Figs. 9 April 17, 1906

CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO

X

THE CALIFORNIA SHORE ANEMONE, *BUNODACTIS XANTHOGRAMMICA*

BY
HARRY BEAL TORREY

XI

SEXUAL DIMORPHISM IN AGLAOPHENIA

BY
HARRY BEAL TORREY and ANN MARTIN

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NOTE TO DESCRIPTION OF PLATE 8.

The material for Plate 8, intended to form a part of this bulletin, was destroyed in the recent fire in San Francisco. The plate will be prepared and published later, and will be sent to all institutions and persons regularly receiving the University of California Publications in Zoology.

UNIVERSITY OF CALIFORNIA PUBLICATIONS

ZOOLOGY

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CONTRIBUTIONS FROM THE LABORATORY

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X.

THE CALIFORNIA SHORE ANEMONE, *BUNODACTIS XANTHOGRAMMICA*.

BY

HARRY BEAL TORREY.

The species which forms the subject of this paper has been described under at least four different specific and five generic names, so that it is now burdened with a formidable, varied and extensive synonymy. This condition of affairs may be explained partly by its wide range and abundance along the entire Pacific coast of North America, coupled with a fair degree of variability. But these very facts make it highly undesirable that its nomenclature should continue to grow and diversify. I have accordingly determined to set forth at once the results of observations which, to my mind, successfully achieve this end, and upon which I have based not only a revision of the species, but a reunion of some ten generic names under the legal title of *Bunodactis,* originally applied by Verrill, '99, to the *Bunodes of Gosse,* and from which the family name is naturally derived. The essential synonymy and the definition of both family, genus and species, are given herewith.

Fam. BUNODACTIDAE Verrill, 1899.

Bunodidae, Gosse, 1858.
Tealidae, Hertwig, 1882.
Cribrinidae, McMurrich, 1901.

Actiniinae with adherent base, column usually tubercular, strongly circumscribed endodermal sphincter, numerous perfect mesenteries, no acontia.

Gen. **Bunodactis** Verrill, 1899.

Cribrina (pars), Ehrenberg, 1834, p. 264.
Bunodes, Gosse, 1855.
Aegeon, Gosse, 1865.
Anthopleura, Duchassaing et Michelloti, 1860.
Aulactinia, Verrill, 1862.
Evactis, Verrill, 1869, p. 470.
Bunodactis, Verrill, 1899, p. 42.
Bunodella, Verrill, 1899, p. 43.
Bunodosoma, Verrill, 1899, p. 44.
Cribrina, McMurrich, 1901, p. 17.

Bunodactidae with naked columns covered by rows of tubercles; tentacles simple, in several cycles; collar with tuberculate margin, with or without acrorhagi; numerous perfect mesenteries.

I agree with McMurrich (:01) that *Evactis* Verrill and *Bunodella* Verrill are synonyms of *Bunodactis* (*Cribrina* McMurrich), and that *Aulactinia* Verrill, *Aegeon* Gosse, and *Bunodosoma* Verrill fall similarly under *Anthopleura* D. and M. For reasons which follow, the process of eliminating generic names has been carried still farther in this paper by the union of *Bunodactis* and *Anthopleura.*

The single character which distinguishes *Anthopleura* from *Cribrina* in McMurrich's definition is the presence of true acrorhagi. In view of the variation of this character in the California species, and the difficulty with which it is recognized in the preserved material, I feel that it is hardly worthy of generic rank. McMurrich (:01, p. 36) has observed that the acrorhagi vary much in distinctness. It is a common experience to find them, in preserved specimens, so contracted and compressed that their tubercular nature is often completely obscured. Even in life

they may be completely concealed by the tentacles and submarginal tubercles, being visible only in certain states of expansion. They may be distinct from the marginal lobed verrucae, or only one of the lobes of the latter, and may be pointed or capitate. They may terminate every row of verrucae or occur irregularly, or be limited to one-half of the collar, or be wanting entirely, even in large and mature individuals.

Bunodactis xanthogrammica (Brandt).

Actinia (Taractostephanus) xanthogrammica, Brandt, 1835, p. 12.
?Actinia (Taractostephanus) elegantissima, Brandt, 1835, p. 13.
Actinia artemisia, Pickering in Dana, 1846, p. 149, Pl. 4, fig. 38.
Evactis artemisia, Verrill, 1868, p. 471.
Evactis ? xanthogrammica, Verrill, 1868, p. 471.
Anthopleura Dowii, Verrill, 1868, p. 474.
Bunodes californica, Fewkes, 1889, p. 124, Pl. 6, figs. 5, 6.
?Cribrina elegantissima, McMurrich, 1901, p. 18, Pl. 1, fig. 7; Pl. 2, figs. 8-14.
Cribrina artemisia, McMurrich, 1901, p. 23, Pl. 2, figs. 15, 16; Pl. 3, figs. 18-20.
Anthopleura xanthogrammica, McMurrich, 1901, p. 36, Pl. 2, fig. 17; Pl. 3, figs. 21-4.
Cribrina artemisia, Torrey, 1902, p. 390, Pl. 25, figs. 1-3.

Column very extensible, with longitudinal rows of adhesive tubercles, which may reach the foot disk, becoming larger distally, and more and more lobed distally; tubercles on the margin of the collar with three to six lobes, the innermost usually taking the form of an inflated acrorhagus, covered with nematocysts.

Tentacles regular, hexamerous, in six cycles, moderate, slightly entacmæous.

Mesenteries. About twenty-five pairs of perfect mesenteries, with broad and moderately heavy longitudinal muscles.

Sphincter pinnately or palmately circumscribed.

Color of San Diego specimens exceedingly variable. Column greenish white to green, brown or pink, always deeper distally. Mouth disk similarly colored, with radiating green stripes marking the courses of the mesenteries; occasionally yellow or white radial stripes. Acrorhagi usually white; may be salmon or orange. Tentacles usually solid whitish to green, occasionally purple distally or proximally, or both, green with whitish or greenish white spots or bands.

Size. Mouth disk may reach the size of 150 mm. with a column 300 mm. or more in length.

Distribution. San Diego, California. Gulf of Panama; Panama; Pearl Islands; Acajutla, San Salvador; California coast; Puget Sound; Sitka, Alaska.

This is the common shore anemone on the California coast from San Diego to San Francisco, probably the only verrucose species occurring in the region between tide marks, according to the observations I have made at San Diego, San Pedro, Santa Barbara (vid. *B. californica* Fewkes), Monterey, and San Francisco. From Verrill's description it would seem to be identical with the Panama species (*A. Dowii*), a view confirmed by the observation of the living animals by several zoological friends.

In spite of this southern range, the same species is found northward along the coast as far as Unalaska. I formerly listed it under the name of *Cribrina artemisia* (1902, p. 390), the material then under observation having been collected at various points between the Aleutian Islands and Puget Sound. A reexamination of this material has demonstrated the presence of acrorhagi, in most cases so flattened and distorted as to have been readily overlooked originally in the contracted specimens. Many individuals were found buried in the sand in the manner noted by McMurrich (p. 23), but the species was equally abundant on the shore rocks. Both habits are characteristic of the California material. The form of the column varies accordingly, very long individuals taken from the sand becoming much shorter than broad in aquaria. Cross sections of the sphincter muscle show conditions which McMurrich has figured as characteristic of *A. xanthogrammica*, *C. artemisia*, and *C. elegantissima*. Both sand and rock dwelling forms almost invariably spurt water from many points on the distal portion of the column when contracting after being taken from the water. This habit is characteristic of *B. artemisia* according to Pickering, and is mentioned in connection with *B. Dowii* by Verrill. It seems to be too constant to be connected with temporary ruptures in the body wall. Permanent openings probably exist, although difficult to find in sections.

Calkins described the appearance of *A. xanthogrammica* as

crystalline. The same adjective describes the specimens from La Jolla which live in the caves. The characteristic green color of the species is found only in individuals exposed to the sun. It is due to the presence of a unicellular alga in the endoderm of the column wall, mesenteries and tentacles. Where sunlight does not penetrate, as under wharves (Calkins), or in caves, the algae, though present, do not develop so luxuriantly as in more exposed situations, and the polyps are correspondingly pale. Similarly, the proximal region of the columns, particularly in those individuals which are largely buried in the sand, is much paler than the distal region.

The foregoing facts lead to the conclusion that Brandt's species extends from Alaska south to Panama, including Pickering's *artemisia* and the California form. I am still doubtful about the position of Brandt's *elegantissima*.

DESCRIPTION OF PLATE 8.

The individual in profile is a representative of the usual green type. All the others came from caves and show in different degrees the absence of the green parasite which gives this species its color. Under the tentacles on the inner side of the single green anemone can be seen the tips of two or three white acrorhagi so characteristic of the species.

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CONTRIBUTIONS FROM THE LABORATORY

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XI.

SEXUAL DIMORPHISM IN AGLAOPHENIA.

BY

HARRY BEAL TORREY and ANN MARTIN.

Sexual dimorphism may be expressed in hydroids by the structure of the gonophores and of the gonangia, as is well known to students of the group. Besides the slight differences in contour which the different sexual elements produce at ripeness in the gonophores of *Tubularia crocea*, for instance, there are constant differences in the form of the flattened processes which represent the tentacles in both sexes (Torrey, :02, p. 43). The female gonophores of *T. marina* (*ibid.*, p. 46) differ still more widely from the males. The male gonangia of *Campanularia pacifica* (*ibid.*, p. 53) are somewhat more slender than the female gonangia, and the same is true in *Plumularia setacea* and other species.

It is not generally known, however, that a similar dimorphism may be exhibited by the modified branches or corbulae which surround and protect the gonophores in the Plumularian genus *Aglaophenia*. Corbulae bear to gonangia the same relation that gonangia bear to gonophores. They are receptacles which may enclose receptacles, in other words. Modifications of their structure in accordance with their sex, therefore, signify more profound changes in the colony than would appear in gonangia or gonophores alone.

The first suggestion that sexual dimorphism may occur in *Aglaophenia* was made by Allman ('83, p. 37). In one of the species obtained by the Challenger Expedition, *Aglaophenia filicula,* he found two kinds of corbulae, which he described and figured. Each was composed of about seven pairs of alternating leaflets. In the one, the leaflets on each side were confluent laterally and carried nematophores on the distal border only. In the other, the leaflets were distinct from base to tip, and not only bore nine nematophores on the distal border but more than half as many on the proximal edge.

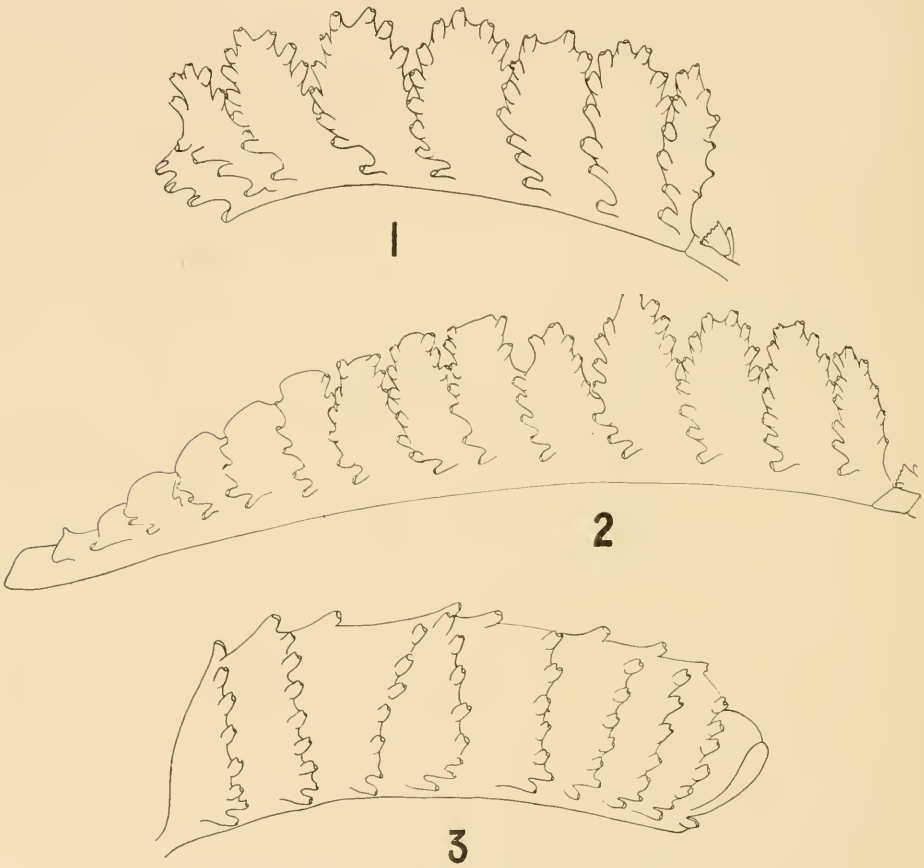
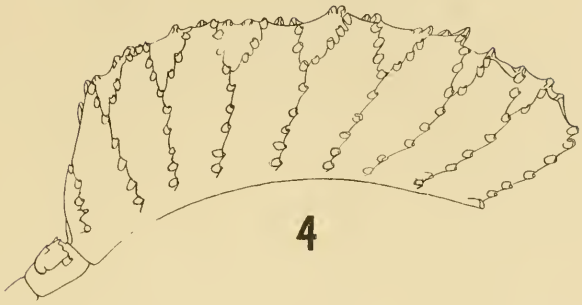
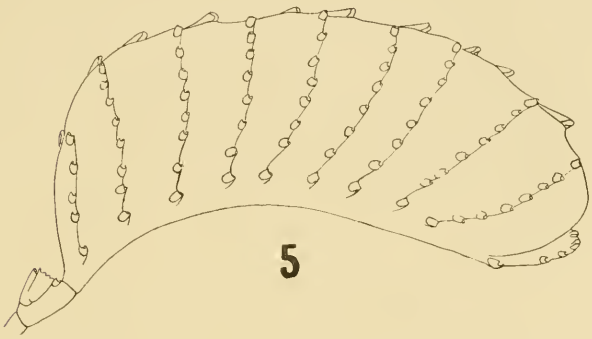
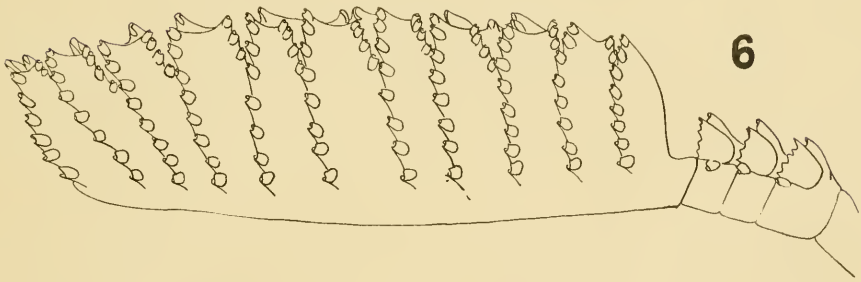


Fig. 1. Male corbula of *A. diegensis,* short type. × 20.
Fig. 2. Male corbula of *A. diegensis,* long type. × 20.
Fig. 3. Female corbula of *A. diegensis.* × 20.







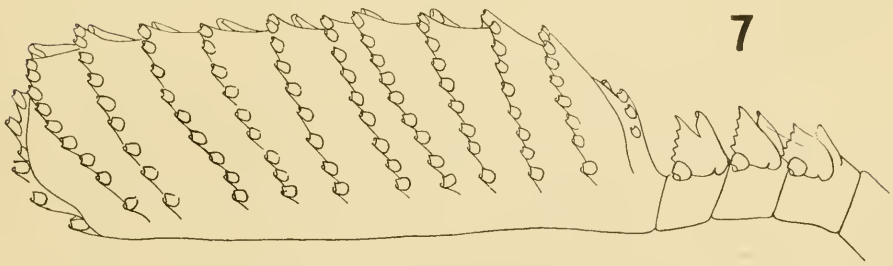
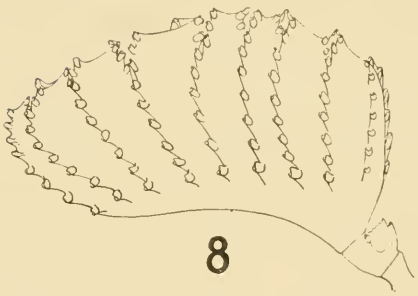


Fig. 4. Male corbula of *A. pluma.* × 20.
Fig. 5. Female corbula of *A. pluma.* × 20.
Fig. 6. Male corbula of *A. struthionides.* × 20.
Fig. 7. Female corbula of *A. struthionides.* × 20.

Allman suggested a number of interpretations for this variation, among them being a possible difference of sex. The corbulae of his specimens were empty, so that he could not establish that view. That it was correct, however, seems to be demonstrated by the discovery of similar conditions in several species of *Aglaophenia* from the California coast. The sexes of the latter were determined without difficulty in each case through the presence of mature gonophores in good condition. There is one difference between Allman's statement and our observations, however. He found both open and closed corbulae "on one and the same colony." That is never the case in the species which we have examined. It is possible that Allman's "colony" may have been a close aggregate of two or more colonies of opposite sexes. These aggregates are not rare in our material, but the same stem never bears more than one kind of corbula.



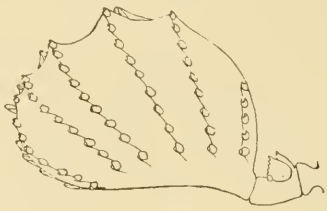


Fig. 8. Male corbula of *A. inconspicua.* × 20.
Fig. 9. Female corbula of *A. inconspicua.* × 20.

In *A. diegensis* Torrey (figs. 1–3), *A. pluma* (Linn.) (figs. 4, 5), *A. struthionides* (Murray) (figs. 6, 7), and *A. inconspicua* Torrey (figs. 8, 9), the corbulae of the two sexes are distinguished by the same characteristic which distinguishes the sexes in *A. filicula* Allman. The female corbulae in all are closed boxes formed by the fusion of contiguous corbular leaflets by their edges. The male corbulae are more or less open, owing to the

incomplete fusion of contiguous leaflets at their tips. The degree of fusion differs slightly among the four species. *A. diegensis* approaches *A. filicula* most nearly in this respect. The gaps between the apical halves of adjacent corbular leaflets, prominent in *A. pluma,* are least noticeable in *A. inconspicua.*

It is significant that the closed corbula surrounds the *female* gonophores. The latter are readily distinguished in all the species examined. In both sexes the gonophores are sessile sporosacs. The regular contour and the central spadix of the ripe male contrast clearly with the more or less irregular contours of the female, with the spadix laterally displaced by the usually single large egg. The embryos develop within the female gonophores for a time, but reach their characteristic long slender form after they have escaped into the corbular cavity. Here they are retained, well protected, until a rupture of the wall sets them free.

The female corbulae in the above species have been described as closed. Between the bases of the corbular leaflets, of both males and females, however, are obscure oblique openings left by the incomplete fusion of the leaflets in this region. As figured by Nutting (:00), the closed corbulae of *A. latirostris* Nutting, *A. gracillima* Fewkes and *A. calamus* Allman are furnished with well defined openings in the same region.

Associated with these openings in *A. struthionides, A. diegensis, A. pluma, A. inconspicua,* and *A. octocarpa,* are two nematophores, smaller and more closely approximated than the rest. They are borne on the proximal edge of each corbular leaflet and are concealed, under ordinary conditions, by the nematophores on the distal edge of the leaflet next adjoining toward the base of the corbula. They are the lowermost of a series of proximal nematophores which are really remains of an originally functional condition. Careful dissection, as Nutting has said, is required to see the others at all.

Open corbulae have been found previously not only in *A. filicula,* but in *A. aperta* Nutting and *A. apocarpa* Allman. In the latter two species, however, open corbulae alone are known and have been regarded as typical for the whole species. Our evidence appears to justify the suspicion that they will prove ulti-

mately to be males. It is also highly probable that other species of *Aglaophenia,* and other genera, may exhibit in their phylactocarps peculiar sex characters corresponding to the foregoing types or to some other type or types not yet discovered.

Zoological Laboratory,
University of California,
Berkeley, Cal., February 23, 1906.

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CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO

XII

ADDITIONS TO THE COPEPOD FAUNA OF THE SAN DIEGO REGION

BY
CALVIN OLIN ESTERLY

Smithsonian Institution
JAN 31 1907
National Museum.

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ZOOLOGY

Vol. 3, No. 5, pp. 53-92, Pls. 9-14 December 10, 1906

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BY

CALVIN OLIN ESTERLY.

The forms dealt with in this paper were obtained principally from two collections made in deep water during the summer of 1905. These collections are Nos. 1030 and 1045. The data are as follows: 1030, plankton, July 20, 1905; 000 net, 400 fathoms to surface, temperature 9.25 C. at 400 fathoms, 2:30 p.m.; 1045 plankton, NW. by W. from La Jolla, 10 miles, July 27, 1905; 000 net, 300 fathoms to surface, temperature 19.3 C. at surface, 4 p.m. Another collection that yielded good material was obtained December 16, 1905, 15 miles west of La Jolla, at 450 fathoms, on a trip to San Clemente Island. A few new forms were taken at other times, and the data will be given with the description of the animals. It has been possible to add a number of forms that are new to the region and were not included in my previous report (Esterly, :05). No claim is made for originality of description in such cases.

The synonymy for genera included in the present paper is not intended to be complete; it is given more for convenience than

for any other reason, and reference is made as a rule only to such works as are more accessible and give description of the genus in question. To compensate for this, a list is appended containing the names and literature references of new species in the genera dealt with here, that have been recorded since the appearance of Giesbrecht's last work ('98). The synonymy of species recorded here for the first time as from this region is given as complete.

It is hoped that the arrangement of figures will at least facilitate comparisons. Drawings of like parts are on the same plates, and if more than one species of a genus is dealt with, the figures are grouped, it is believed, so that comparison of one with another will be easy. This may be said also for different genera, since, for example, the fifth feet of males or females are all on one plate, whether they belong to animals in the same genera or not.

The following is a list of the species treated in this paper:—

	PAGE
Spinocalanus major n. sp.	55
Gaetanus brevicornis n. sp.	56
Gaetanus unicornis n. sp.	57
Gaetanus clarus n. sp.	57
Chirundina streetsi Giesbrecht	59
Euchirella curticauda Giesbrecht	59
Euchaeta californica n. sp	60
Euchaeta propinqua n. sp.	61
Euchaeta tenuis n. sp.	61
Euchaeta spinifera n. sp.	62
Euchaeta dubia n. sp.	63
Euchaeta tonsa Giesbrecht	64
Scolecithrix frontalis Giesbrecht	65
Scolecithrix magna (Scott)	66
Scolecithrix inornata n. sp.	67
Xanthocalanus similis n. sp.	68
Metridia princeps Giesbrecht	69
Metridia atra n. sp.	70
Metridia ignota n. sp.	71
Disseta grandis n. sp.	72
Augaptilus rostratus n. sp.	73
Arietellus major n. sp.	74
Labidocera jollae n. sp.	74
Pontellopsis occidentales n. sp.	76
Calanus robustior Giesbrecht	77
Heterorhabdus longicornis Giesbrecht	77
Heterorhabdus spinifrons Claus	77

Family CALANIDAE.

Genus **Spinocalanus** Giesbrecht.

Spinocalanus, Giesbrecht ('92), p. 52, 209; ('98), p. 31.
Spinocalanus, Sars (:01), p. 22.

Female: Resembling *Clausocalanus* in general. Cephalothorax of four segments, rostrum wanting. Abdomen of four segments, symmetrical. Anterior antennae 24-jointed; maxilla, maxillipeds, and swimming feet set with spines, the feet as in *Clausocalanus*, but of the usual shape, and terminal joint of outer ramus in second to fourth pairs with five inner marginal bristles. Fifth pair of feet absent.

Male unknown.

Spinocalanus major n. sp.

Female: Closely resembles *S. abyssalis* Giesbrecht. Head, and last thoracic segment rounded, not produced. Fourth joint of inner ramus of posterior maxilliped with an outer marginal bristle (lacking in *S. abyssalis*). The outer marginal bristles of the first and second joints of the outer ramus of the first foot are much shorter and stouter than in *S. abyssalis*, and the inner margin of those joints is provided with long and rather heavy bristles, no such character appearing in *S. abyssalis*.

Length: 1.6 mm.

Coloration: Whitish, translucent, but without pigment.

Occurrence: One female. Coll. 946; plankton taken with Kofoid water bucket NW. by W. from La Jolla, 5 miles, June 30, 1905; 200 fathoms. Depth at station, 210 fathoms. Temperature 9.5 C. at 200 fathoms. Midday.

In the absence of figures, the rounded last thoracic segment in *S. major* seems to distinguish it from *S. magnus* Wolfenden, in which the "last thoracic segment is produced on each side." The latter species is considerably the larger.

Genus **Gaetanus** Giesbrecht.

Gaetanus, Giesbrecht ('92), p. 53, 219; ('98), p. 32.

Female: Rostrum short, with one point. The front of the head on the dorsal surface bears a median spine (Pl. 9, figs. 3, 4, 5). Cephalothorax and abdomen symmetrical, each of four segments, the last thoracic segment lengthened on each side into a long spine (Pl. 10, fig. 24). Anterior antennae 23- or 24-jointed; inner ramus of the posterior antennae about four-fifths as long as the outer ramus. Outer ramus of the first foot 2- or 3-jointed, inner ramus of the second foot 2-jointed. Inner border of the first basal of the fourth foot provided usually with lamellae or spines at the distal portion instead of bristles (Pl. 13, fig. 76).

Male: Head with the spine which is characteristic of the genus. Abdomen of five segments. Anterior antennae 22-jointed; mouth parts retrograded. Fifth feet much as in *Gaidius;* outer ramus of each foot 3-jointed, inner rami rudimentary and 1-jointed. The inner ramus of the left foot is slender and rod-shaped, that of the right foot heavy and club-shaped (Pl. 14, fig. 90).

Gaetanus brevicornis n. sp.

Pl. 9, fig. 4; pl. 12, fig. 55.

Female: Head (Pl. 9, fig. 4) with a spine and quite similar to *G. armiger* Giesbrecht, but heavier. Anterior antennae extend about to the end of the furca. The second joint of the outer ramus of the posterior antenna has a small process, as in *G.armiger*. The lamellar process on the first basal of the posterior maxilliped (Pl. 12, fig. 55) is more prominent than in *G. miles*. The outer ramus of the first foot is indistinctly 2-jointed, first basal of fourth foot with a row of delicate hairs, quite different from the tube-like bristles of *G. miles,* and not so heavy even as in *G. armiger*.

Length: 4.3 mm.

Coloration: Opaque and without pigment.

Occurrence: One female, Coll. 1030. Type in the collection of the University of California.

G. brevicornis resembles the female of *G. armiger* Giesbrecht chiefly in the form of the head. There are specific differences in the posterior maxilliped, in which the lamella on the basal joint is longer and more prominent than in *G. miles*, while in *G. armiger* it is only indicated. There is no reason for considering *G. brevicornis* the same as *G. major* Wolfenden or *G. caudani* Wolfenden (Canu?), since the lamella is present on the posterior maxilliped (absent in *G. major*); the cephalic spine is similar to *G. armiger* (in *G. caudani* it resembles *G. miles*). The single specimen of *G. brevicornis* is very nearly adult. The length is greater than that of *G. armiger* (3.2 mm) and less than that of *G. major* (5 mm. or more).

Gaetanus unicornis n. sp.

Pl. 9, fig. 3; pl. 12, fig. 54; pl. 13, fig. 76.

Female: A large *Gaetanus* in which the cephalic spine is very long and straight, pointing slightly up instead of down (Pl. 9, fig. 3). The anterior antennae are 24-jointed and as held in the dead animal reach beyond the furca by at least the last four joints. The second joint in the outer ramus of the posterior antennae is without a process; the lamella on the first basal of the posterior maxilliped is present, but does not have the rod-like extension of *G. brevicornis* or *G. miles* (Pl. 12, fig. 54). The outer ramus of the first foot is distinctly 2-jointed, and the first basal of the fourth foot (Pl. 13, fig. 76) has tube-like bristles resembling those in *Gaidius*.

Length: Adult females, 6.5 mm.

Coloration: Rather opaque and without pigment in formalin.

Occurrence: Six females, Coll. 1045. Type in the collection of the University of California.

Gaetanus clarus n. sp.

Pl. 9, fig. 5; pl. 14, fig. 90.

Male: Head and spine resembling *G. miles*, but the spine is longer and the front of the head below it protrudes considerably (Pl. 9, fig. 5). The anterior antennae are about as long as the

cephalothorax, and the first basal of the posterior maxilliped is without the lamellar appendage; the rest of the oral organs are considerably retrograded. The outer ramus of the first foot is indistinctly 3-jointed; the first basal of the fourth foot is without the tube-like bristles or hairs characteristic of the female of the genus. The fifth feet (Pl. 14, fig. 90) as described for the genus. The distal end of the inner margin of the second joint of the outer ramus in the right foot has a group of four or five heavy spines.

Length: 5.3 mm.

Coloration: Semi-translucent in formalin and without pigment.

Occurrence: Two males, Coll. 1045. Type in the collection of the University of California.

The spine on the head distinguishes these animals as *Gaetanus,* and the shape of the spine and the head from the other members of the genus.

Genus **Chirundina** Giesbrecht.

Chirundina, Geisbrecht ('95), p. 245.

Female: Allied to *Undeuchaeta* and *Euchirella.* Rostrum 1-pointed, short; forehead with crest (Pl. 9, fig. 2); lateral angles of last thoracic segment (Pl. 10, fig. 28) produced into short, blunt processes. Inner ramus of second antennae half as long as outer; maxilla as in *Euchirella,* but bristles more numerous. Outer ramus of first foot 2-jointed; first basal of fourth foot without spines.

Male (new): Like female in general characters, except that the last thoracic segment is not produced, but smoothly rounded. Outer ramus of first foot 3-jointed (Pl. 12, fig. 58). Fifth feet somewhat resembling those of *Gaidius* or *Gaetanus;* each foot biramus, inner rami 1-jointed, outer rami 3-jointed; inner ramus of right foot club-shaped, that of left foot long and slender; the terminal joint of the outer rami is spine-like (Pl. 14, fig. 86, 87).

Chirundina streetsi Giesbrecht.

Pl. 9, fig. 2; pl. 10, fig. 28; pl. 12, fig. 58; pl. 14, figs. 86, 87.

Chirundina streetsi, Giesbrecht ('95), p. 250, pl. 1, figs. 5-10.
Chirundina streetsi, Giesbrecht ('98), p. 34.

With the characters of the genus.

Length: Male, 4.3 mm. Female, 5 mm.

Coloration: Whitish in formalin, but without pigment.

Occurrence: Two females, one male, Coll. 1030.

The male is new. There can be little doubt that the specimen is a *Chirundina*, although the structure of the fifth feet might place it in *Gaidius* or *Gaetanus*.

Genus **Euchirella** Giesbrecht.

Euchirella, Giesbrecht ('92), p. 54, 232; ('98), p. 34.
Euchirella, Esterly (:05), p. 150.

Euchirella curticauda Giesbrecht.

Pl. 9, fig. 6; pl. 10, fig. 27; pl. 12, fig. 62; pl. 13, fig. 67.
Euchirella curticauda, Giesbrecht ('92), p. 233, pl. 15, figs. 3, 13, 25; pl. 36, figs. 19, 20; ('98), p. 36.
Euchirella curticauda var. *atlantica*, Wolfenden (:04), p. 116.

Female: Forehead (Pl. 9, fig. 6) with a high crest, rostrum lacking. Abdomen (Pl. 10, fig. 27) short, less than one-sixth as long as the cephalothorax, symmetrical. Anterior antennae as long as the cephalothorax; inner ramus of posterior antennae one-fourth as long as outer ramus, first joint of latter with a knob-like projection (Pl. 12, fig. 62); second joint of outer ramus with five bristles. First joint of outer ramus of fourth foot with a series of ten to thirteen tooth-like spines on the inner margin (Pl. 13, fig. 67).

Male unknown.

Length: Female, 3.6 mm.

Coloration: Opaque, without pigment.

Occurrence: Two females, Coll. 1030.

Genus **Euchaeta** Philippi.

Euchaeta, Giesbrecht ('92), p. 55, 245; ('98), p. 37.
Euchaeta, Esterly (:05), p. 156.

Euchaeta californica n. sp.

Pl. 9, fig. 11; pl. 10, figs. 26, 34.

Female: Eminence on forehead low; last thoracic segment rounded laterally, with a heavy tuft of hairs on each side (Pl. 10, fig. 34). Genital segment symmetrical (Pl. 10, fig. 26), the genital swelling large and with two low flanges guarding the orifice (Pl. 9, fig. 11). The anterior antennae are not as long as the cephalothorax; first outer marginal lobe of the maxilla with seven bristles. The outer ramus of the first foot is clearly 2-jointed, and there is a very small bristle in the middle of the concave outer border of the first joint; the distal bristle of this joint reaches half-way to the end of the terminal joint of the ramus. The terminal bristle is long and slender. In the second foot the external spine of the first joint of the outer ramus reaches well beyond the end of the first outer marginal spine of the third joint. The second outer marginal of this joint is very long, reaching to the end of the third outer marginal; the border of the third joint is deeply concave between the second and third external spines.

Length: Female, 8 mm.

Coloration: Rather opaque, red in bristles of maxillipeds and feet. The hairs on the furcal bristles are iridescent.

Occurrence: One female, Coll. 1030, and on the winter trip to San Clemente. Type in the collection of the University of California.

The shape of the genital segment will distinguish *E. californica* from the other members of the genus, except possibly *E. flava* Giesbrecht. The size of the latter (3.2 mm), and the number of bristles on the proximal outer lobe of the maxilla (five in *flava*, seven in *californica*), are distinguishing characters.

Euchaeta propinqua n. sp.

Pl. 9, fig. 9; pl. 10, figs. 30, 33.

Female: Approaching *E. californica* in general. The shape of the head in lateral view is different, the frontal eminence being lower and hardly visible; the rostrum is shorter and heavier (Pl. 9, fig. 9). The genital segment is symmetrical, and has the flanges guarding the orifice, as in *E. californica*, but they protrude much farther ventrally and there is a knob-like swelling behind, between them (Pl. 10, figs. 30, 33). The segment is not so swollen laterally as in *E. californica*. The terminal joint of the anterior antennae is longer in *californica* than in *propinqua* by one-fifth the length of the joint in the latter; and the terminal joint in *propinqua* exceeds the next by almost one-sixth the length of the former, or one-fifth the length of the latter. First foot as in *E. californica*. In the second foot the marginal bristle of the second joint of the outer ramus does not reach the end of the first marginal of the third joint, nor does the second marginal of the third joint reach the base of the third marginal by about the length of the latter. (In *californica* the second marginal reaches to the end of the third.)

Length: Female, 9 mm.

Coloration: Rather opaque, no pigment in antennae; red in the mouth parts and feet, including the bristles, and in the body immediately adjacent to the mouth parts.

Occurrence: One female on the winter trip to San Clemente. Type in the collection of the University of California.

Euchaeta tenuis n. sp.

Pl. 9, fig. 12; pl. 10, figs. 29, 31.

Female: Eminence on forehead slightly protruding (Pl. 9, fig. 12). Sides of last thoracic segment rounded, sparsely pubescent (Pl. 10, fig. 29). Genital segment with a long flap guarding the orifice on the right; the segment is otherwise symmetrical (Pl. 10, fig. 31). The second terminal bristles of the furca are much longer than any of the others. Anterior antennae reaching the end of the furca; the last joint is longer than the preceding

one by about one-sixth the length of the latter. First outer marginal lobe of the maxilla with eight bristles, inner ramus with four. Outer ramus of first foot 2-jointed, without spine in middle of outer border of first joint; the distal spine of the joint extends well beyond the end of the second joint. The distal spine of the second joint of outer ramus of the second foot reaches to the end of the first outer marginal spine of the third joint; the middle spine of the third joint reaches over half way to the base of the third outer marginal.

Length: Female, 6 mm.

Coloration: Rather translucent, with a light shade of red along the sides of thoracic segments and in the feet.

Occurrence: One female, Coll. 1045. Type in the collection of the University of California.

The form of the genital segment is a sufficiently distinct character for this species.

Euchaeta spinifera n. sp.

Pl. 9, fig. 8; pl. 11, fig. 35; pl. 14, figs. 82, 83.

Male: Head (Pl. 9, fig. 8) much as in the female of *E. tenuis;* last thoracic segment long, rounded at the sides, and with a curved, thorn-like projection on the dorsal margin (Pl. 11, fig. 35). Abdomen with genital and anal segments equal in length, the second segment longer than any other, and nearly as long as the last two. Anterior antennae reaching to end of furca. First foot with 3-jointed outer ramus, the outer marginal of the first joint very small. In the second foot the outer margin of the third joint of the outer ramus is deeply concave distal to the middle spine; the outer marginals are all short and blunt, except the middle spine of the third joint, which reaches half way to the base of the third. The fifth feet are slender; inner ramus of the left foot half as long as the first joint of the outer ramus. The second joint of the ramus ends distally in a pyramidal toothed process (Pl. 14, figs. 82, 83). The terminal joint of the outer ramus of the right foot ends bluntly.

Length: Male, 5.1 mm.

Coloration: No pigment in body or appendages, but the plumose bristles of the feet and furca are iridescent.

Occurrence: Two males, Coll. 1030. Type in the collection of the University of California.

These animals are distinct from any males of the genus hitherto described, and may belong to some species described from the female. I prefer to consider them new, especially since no females were taken in Coll. 1030 that even remotely suggest a relationship, although the shape of the head is like that of *E. tenuis*. That species, however, was obtained in Coll. 1045. Possibly additional material will make it clear to what species the animals belong. It is certainly as safe to make new species of unknown males as to guess at relationships, in view of the sexual dimorphism which extends to other structures than the fifth pair of feet.

Euchaeta dubia n. sp.

Pl. 9, fig. 7; pl. 11, fig. 36; pl. 13, fig. 66; pl. 14, figs. 84, 85.

Male: Head regularly rounded (Pl. 9, fig. 7), without eminence. Last thoracic segment rounded laterally. Genital and anal segments of equal lengths, second segment as long as the last two; the genital segment has a low, rounded projection on the dorsal border as seen in side view (Pl. 11, fig. 36). Anterior antennae as long as the cephalothorax; first foot with 3-jointed outer ramus, first joint without outer marginal. Third joint of outer ramus of second foot with concave outer border between second and third outer marginals; first outer marginal not reaching base of second. Outer margin of the joint from base of second marginal to base of third, two and one-half times as long as the length of the former spine (Pl. 13, fig. 66). Fifth feet (Pl. 14, figs. 84, 85) of the usual form, inner ramus of left foot very small, about one-seventh the length of the first joint of the outer ramus. The toothed projection at the end of the second joint is bifid at the distal end, and the portion on the inner margin carries small denticulations.

Length: Male, 7.8 mm.

Coloration: Without pigment, but furcal bristles are iridescent.

Occurrence: Two males, Coll. 1030, two on the winter trip to San Clemente. Type in the collection of the University of California.

It will be seen that these animals occurred in two collections; in one of these (1030) *E. californica* was found and in the other *E. propinqua*. It is difficult to say with any certainty whether the males belong to one species or the other, and for that reason, and in the absence of structures pointing one way or the other, I have kept the sexes in separate species. Possibly immature forms will be found later that will make clear the true relations.

Euchaeta tonsa Giesbrecht.

Pl. 9, fig. 10; pl. 10, fig. 32.

Euchaeta tonsa, Giesbrecht ('95), p. 251, pl. 3, figs. 9, 10; ('98), p. 40.

Female: The species lies in the group with *norvegica*, *flava*, and *californica*, but is distinct from them in the absence of the tufts of hair on the last thoracic segments; the segment instead of being rounded laterally ends in a small tooth (Pl. 10, fig. 32). The frontal eminence (Pl. 9, fig. 10) is rather high and slightly protruding. The shape of the genital segment is different from that in any of the allied species; the eminence is prominent and lies far back in the segment, so that its posterior border almost coincides with that of the segment, and the hirsute transverse line behind the eminence is lacking. The first lobe on the outer border of the maxilla has nine bristles (*norvegica* nine, *flava* five, *californica* seven). The terminal joint of the outer ramus of the second foot is similar to that in the other species; the middle bristle on the outer margin reaches beyond the base of the third.

Length: Female, 6.1 mm.

Coloration: Body rather opaque, without pigment. The distal bristles of the posterior maxilliped and all those of the anterior are a magenta red.

Occurrence: Twelve females, Coll. 1030.

Genus **Scolecithrix** Brady.

Scolecithrix, Brady ('83), p. 56.
Scolecithrix, Giesbrecht ('92), p. 56, 265, 764; ('98), p. 41.
Scaphocalanus, Sars, (:00), p. 35.
Scolecithrix, Esterly (:05), p. 163.

The genus *Scolecithrix* of Giesbrecht contains a large number of species, all of which have been retained in the genus by Gies-

brecht, although he formed the genus *Lophothrix* (Giesbrecht, '95) to receive a certain form which later (Giesbrecht, '98) he returned to *Scolecithrix*. In his opinion the genera *Amallophora* Scott, *Scaphocalanus* Sars, and *Lophothrix* Giesbrecht belong to *Scolecithrix* Brady. Sars (:02b, pp. 50, 54, 57) recognizes the genera *Amallophora* and *Scolecithricella* in *Scolecithrix*, and forms a new family, Diaixidae, and the genus *Diaixis* to receive *Scolecithrix hibernica* Scott. *Scolecithricella* Sars includes such species as *Scolecithrix minor* Brady (Sars, :02, p. 54), in which the sensory appendages of the anterior maxilliped are all vermiform, and the fifth feet are present in the female, but 1-jointed and lamellar. Sars (:02b, p. 51) also considers his genus *Scaphocalanus* (Sars, :00, p. 35) to be identical with *Amallophora magna* Scott, which, according to Giesbrecht ('98, p. 45), is probably the same as *Scolecithrix cristata* Giesbrecht. Sars (:02b, p. 55) is also of this opinion. Wolfenden (:04, p. 120) also favors the division of the sub-family Scolecithricinae (genus *Scolecithrix?*) into the genera *Scolecithrix*, *Amallophora*, and *Lophothrix*. Giesbrecht (:02, p. 26, foot-note) states that in his opinion the large number of species in *Scolecithrix* can not be separated into well-defined genera, and, from what I know of the group, this is my belief also. Accordingly I shall, for the present at any rate, treat all the members of *Scolecithrix* as belonging to the same genus. It may be well to state that Giesbrecht (:02, p. 26) recognizes the new genus *Racovitzanus* in the sub-family on the basis of the unpaired rostrum and the presence of a rudimentary inner ramus on the fifth pair of feet in the female.

Scolecithrix frontalis Giesbrecht.

Pl. 9, fig. 14; pl. 13, fig. 70.

Lophothrix frontalis, Giesbrecht ('95), p. 254, pl. 3, figs. 1-3.
Scolecithrix frontalis, Giesbrecht ('98), p. 49, fig. 10.

Female: Forehead lengthened, with a low crest (Pl. 9, fig. 14); last thoracic segments fused. The second and third segments of the abdomen are broader than long, the third slightly shorter than the first. Anterior antennae 24-jointed, reaching about to the end of the body; rami of posterior antennae about

equal in length; second basal of maxilla with five bristles, inner ramus with eight, outer with nine. Anterior maxilliped with pencillate appendages. First joint of outer ramus of first foot without marginal spine. Fifth foot 3-jointed, terminal joint not much longer than the others, with three heavy bristles (Pl. 13, fig. 70).

Length: Female, 6 mm.

Coloration: Rather opaque and without pigment.

Occurrence: Common through summer of 1905 in deeper hauls.

Scolecithrix magna (Scott).

Pl. 9, fig. 13; pl. 11, fig. 38; pl. 12, figs. 52, 64; pl. 13, fig. 72.

Scolecithrix cristata, Giesbrecht ('95), p. 252, pl. 2, figs. 6-8; pl. 3, figs. 1-5; ('98), p. 48, fig. 8.
Amallophora magna, Scott ('93), p. 55, pl. 4, figs. 5-9.
Amallophora magna, Sars (:02b), p. 55, pls. 34-35.
Scaphocalanus acrocephalus, Sars (:00), p. 36, pls. 7, 8, 9; (:02b), p. 51.

Female: Forehead (Pl. 9, fig. 13) with a low and rather long crest; last two thoracic segments fused; rostral filaments long and slender. The last thoracic segment ends laterally in a small rounded projection (Pl. 11, fig. 38). The two middle segments of the abdomen are about equal in length, shorter than the genital segment, and about twice as long as the anal segment. Anterior antennae 22-jointed, reaching a little beyond the cephalothorax. Second basal of maxilla with four bristles, inner ramus with seven. Sensory appendages of anterior maxilliped pencillate and vermiform. First basal of fourth foot with plumose inner marginal; first joint of outer ramus of first foot (Pl. 12, fig. 52) without marginal bristle, second joint with a very small one and third joint with a large one. Marginal spine of second joint of outer ramus of second foot longer than the curved marginal of the first joint or than those of the third (Pl. 12, fig. 64). Third foot, and especially the fourth, with shorter spines. Fifth foot (Pl. 13, fig. 72) 2-jointed, with three bristles at the end, the one on the inner margin being the longer; the outer marginal is small.

Length: Female, 4.4 mm.

Coloration: Rather opaque and without pigment.

Occurrence: One female, Coll. 1030.

This animal is undoubtedly *S. magna* (Scott), although the fifth feet vary slightly from his and Giesbrecht's drawings, especially in the relative and actual lengths of the spines.

Scolecithrix inornata n. sp.

Pl. 9, fig. 18; pl. 11, fig. 37; pl. 13, figs. 65, 73.

Female: Head without crest, regularly rounded (Pl. 9, fig. 18). Last thoracic segment rounded at sides, but with an indentation above and below the middle of the posterior border (Pl. 11, fig. 37). Genital segment as long as the next two, the second as long as the third and anal together; the anal segment is about half as long as the preceding one. All of the abdominal segments are broader than long. The maxilla has four bristles on the second basal, eight on the outer ramus, and seven on the inner ramus; first outer marginal lobe with nine. The anterior maxilliped has three vermiform and five pencillate sensory appendages. First foot with 3-jointed outer ramus, all the joints having outer marginal spines, those of the first two being of equal lengths. The outer marginals of the outer ramus of the second foot are all of nearly equal lengths; the faces of the rami are set with spines, the larger ones being on the inner ramus. The teeth of the terminal saw are very closely set (Pl. 13, fig. 65). The spines become smaller in the third and fourth pairs. The fifth feet are 2-jointed, with two heavy terminal spines, the inner one being slightly larger (Pl. 13, fig. 73).

Length: Female, 4.3 mm.

Coloration: Slight yellowish tinge to the body, in formalin.

Occurrence: One female, Coll. 1030. Type in the collection of the University of California.

The fifth feet resemble those of *S. auropecten* Giesbrecht, but the bristling of the maxilla and the relative sizes of the animals (*auropecten* 1.8 mm. long) are distinguishing characters.

Genus **Xanthocalanus** Giesbrecht.

Xanthocalanus, Giesbrecht ('92), p. 57, 286; ('98), p. 49.

Head separate from thorax, fourth thoracic segment fused with fifth. Abdomen of female 4-segmented, symmetrical. Anterior antennae reaching to end of body at least, 24-jointed. Abdomen of male 5-segmented; right anterior antenna 17-jointed. Anterior maxilliped provided with characteristic sensory appendages, some of them pencillate (Pl. 12, fig. 60). The mandible, maxilla, and first maxilliped reduced in the male, the latter with but one pencillate sensory appendage. Swimming feet of both sexes as in *Scolecithrix;* fifth feet in female 2-, 3-, or 4-jointed. The right fifth foot is lacking or shortened in the male, the left uniramous 5-jointed.

Xanthocalanus similis n. sp

Pl. 9, fig. 1; pl. 10, fig. 24; pl. 12, figs. 60, 61; pl. 13, figs. 71, 77.

Female: Head with a crest, rostrum short and heavy, bifid; the last thoracic segment ends laterally in sharp angles, but not spines (Pl. 9, fig. 1). Genital and anal segments equal in length, the second segment the longest of the four. Anterior antennae extend back as far as the posterior border of the cephalothorax. The anterior maxilliped has seven pencillate sensory appendages and one long, vermiform process (Pl. 12, fig. 60), and a very long, heavy, curved hook on the terminal lobe. The second maxilliped has a short pencillate sensory process on the outer margin of the first basal near the base of the joint. Swimming feet as in other species of the genus, except that the terminal saw in the second, third (Pl. 13, fig. 71), and fourth pairs has a second row of teeth inside the usual denticulations. The second row, extending from the base of the saw, is about one-third the length of the latter. The fifth feet are clearly 4-jointed (Pl. 13, fig. 77) and thickly covered with spines; the last joint ends in two short, heavier spines, the terminal one longer than the outer one. There is a somewhat similar terminal spine on the outer margin of the third joint of the foot.

Length: Female, 6.5 mm.

Coloration: Whitish, translucent, and without pigment.

Occurrence: One female, Coll. 1030. Type in the collection of the University of California.

This species resembles *X. cristatus* Wolfenden (:04, p. 119, pl. 9, figs. 18, 19), but differs from it in the number of joints of the fifth feet, his specimen having 3-jointed feet. The fifth pair being 4-jointed in *X. similis* makes it distinct from all other species. The presence of the second row of teeth or serrations on the terminal saw of the last three pairs of swimming feet is a distinctive character also; at least Wolfenden does not mention such a point. The anterior antennae in *similis* are longer than in *critatus*.

X. similis closely resembles *Scolecithrix chelifer* I. C. Thompson (:03, p. 21, pl. 5, figs. 1-9) in the possession of two rows of teeth on the terminal saws; and the drawing Thompson gives of the mandible (anterior maxilliped?) (fig. 4) is much like the anterior maxilliped in *X. similis* or *X. cristatus* Wolfenden (:04, p. 119) in the possession of the heavy hook. However, Thompson's species has the anterior antennae 23-jointed, and the head does not seem to be distinct from the thorax. These characters, as well as the absence of the crest on the head, make it doubtful if *S. chelifer* is the same as *X. similis*.

Family CENTROPAGIDAE.

Genue **Metridia** Boeck.

Metridia, Giesbrecht ('92), p. 61, 339; ('98), p. 105.
Metridia, Esterly (:05), p. 177.

Metridia princeps Giesbrecht.

Pl. 11, fig. 41; pl. 13, fig. 79; pl. 14, fig. 97.

Metridia princeps, Giesbrecht ('92), p. 340, pl. 33, figs. 3, 18, 35, 40; ('98), p. 107.
Metridia princeps, Thompson (:03), p. 24, pl. 6, figs. 3, 4. (Male.)

Female: Forehead seen from above is truncate, rostral filaments borne on a papilla; sides of last thoracic segments rounded. Abdomen 3-jointed, genital segment longer than last two; anal

segment half as long as middle one. Furcal blades five or six times as long as broad. Anterior antennae reaching beyond end of furca by about the last joint. Fifth feet 4-jointed, last joint with three apical bristles, all of which are plumose; the basal joint with a tuft of long hairs (Pl. 13, fig. 79).

Male: Similar to female, but head not as broad, and furca not entirely symmetrical (Pl. 11, fig. 41). Abdomen 5-jointed, anal and genital segments of equal lengths; the third segment is the longest of the five. Grasping antenna on the left side, reaching back to end of furca. First joint of fifth foot on right side (Pl. 14, fig. 97) with a long spine.

Length: Female, 8-8.5 mm. Male, 7-8 mm.

Coloration: Very translucent and without pigment.

Occurrence: Two males were taken with five females which are undoubtedly *M. princeps*. Coll. 1030.

Metridia atra n. sp.

Pl. 9, figs. 15, 16; pl. 11, figs. 39, 40; pl. 13, fig. 78; pl. 14, fig. 95.

Front of head produced into a rather prominent process, rostral filaments long, slender, and plumose (Pl. 9, fig. 15). The sides of the last thoracic segment end in a strong point; furca symmetrical in both sexes, each blade as broad as long (Pl. 11, fig. 39). The anal segment has on each side a bluntly conical projection which reaches back about to the base of the outer marginal furcal bristle (Pl. 11, figs. 39, 40). The furca has a blunt process between the two outer terminal bristles (Pl. 11, fig. 39). The inner marginal or dorsal furcal bristle is extremely slender as compared with the others. The anterior antennae of the female are 23-jointed and reach beyond the furca; grasping antenna on right side. Right fifth foot of male longer than the left; second and third joints of outer ramus of right foot with spines on inner border, second joint of outer ramus of left with a heavy process extending along outer border (Pl. 14, fig. 95). Fifth foot of female 4-jointed, the last joint with three apical bristles, the innermost not plumose (Pl. 13, fig. 78).

Length: Female, 11.5-12 mm. Male, 9 mm.

Coloration: Both sexes are alike; black pigment in cephalothorax except the most anterior portion of the head; it is absent.

from the abdomen (except for traces), anterior and posterior antennae, but abundant in the feet and their bristles. The color is striking, since it gives the animal as a whole a black or grayish black appearance.

Occurrence: Three males, one female, Coll. 1030. Type in the collection of the University of California.

The species is probably allied to *M. scotti* Giesbrecht, but the presence of spines on the inner border of the right fifth foot seems to be a specific character.

Metridia ignota n. sp.

Pl. 9, fig. 20.

Female: Forehead slightly protruding (Pl. 9, fig. 20) into a rounded projection, below which the frontal hairs are situated on a rounded eminence. Rostrum rather stiff. The last thoracic segment is rounded at the sides and rather truncate. The furca is six times as long as broad and as long as the anal segment. The latter is only slightly shorter than the genital segment, and the genital segment is twice as long as the middle segment. The basal joint of the anterior antennae has three straight spines, of which the middle one is the shortest. The fifth feet are 4-jointed, terminal joint with three bristles of about equal lengths; the second joint has a spinose bristle on the outer margin which reaches beyond the end of the last joint of the foot; the third joint is provided with a stout spine on the outer margin.

Length: Female, 5.8 mm.

Coloration: Very translucent, no pigment.

Occurrence: One female, Coll. 1030. Type in the collection of the University of California.

M. ignota resembles *M. princeps* Giesbrecht somewhat, but the shape of the head, the relative lengths of the abdominal segments, and the fifth feet will distinguish the two.

Genus **Disseta** Giesbrecht.

Disseta, Giesbrecht ('92), p. 63, 369; ('98), p. 112.

Female: Allied to *Lucicutia* Giesbrecht. Left half of furca larger than the right (Pl. 11, fig. 45), and bristles longer and

thicker, especially the second terminal. Rostral filaments long and fairly stout, springing from a papilla. Fourth and fifth thoracic segments fused, abdomen 4-segmented. Anterior antennae 25-jointed; mouth parts as in *Lucicutia* except that the first outer marginal lobe of the maxilla has nine bristles. Rami of all the feet 3-jointed; the inner marginal bristle of the second joint of the outer ramus of the fifth pair is awl-shaped (Pl. 13, fig. 69); the terminal joint of the inner rami of the second and third feet has eight bristles (instead of five or six), that of the fifth feet with six.

Male (new): Head rounded, separate from thorax, last two thoracic segments fused. Abdomen 5-segmented, left blade of furca longer than right. Grasping antenna on left side, 21-jointed, longer than body, portion beyond the geniculation 4-jointed; mouth parts as in female. Fifth feet not grasping organs (Pl. 14, figs. 88, 94), with 3-jointed rami; the outer rami are similar in both feet, though not identical; second basal of each side with a hirsute, flap-like appendage, that of the left foot the longer; terminal joints of inner rami with six bristles. Terminal spine of outer ramus of right foot (Pl. 14, fig. 94) longer than that of the left (Pl. 14, fig. 88); second joint of outer ramus of left foot with a heavier process than in the right foot.

Disseta grandis n. sp.

Pl. 9, fig. 21; pl. 11, figs. 45, 46; pl. 13, fig. 69; pl. 14, figs. 88, 94.

Female: Rather closely resembling *D. palumboi* Giesbrecht, but much larger (*D. palumboi* 5.7 mm.). There are also differences in the structure of the fifth feet and mandibular blade, and the last thoracic segment is asymmetrical, being longer on the left side. The genital segment has a rather more rounded outline than in *D. palumboi*, the orifice is of a different shape, and the segment is asymmetrical (Pl. 11, fig. 46).

Male: Characterized in the generic description.

Length: Female, 8.3 mm. Male, 7.6 mm.

Coloration: The females have a slight amount of orange material in the intestine and the feet are reddish; the males are translucent and without pigment.

Occurrence: Three males and three females, winter trip to San Clemente. Types in the collection of the University of California.

Genus **Augaptilus** Giesbrecht.

Augaptilus, Giesbrecht ('92), p. 65, 400; ('98), p. 120.
Augaptilus, Esterly (:05), p. 187.

Augaptilus rostratus n. sp.

Pl. 9, fig. 19; pl. 11, fig. 42; pl. 12, figs. 57, 63; pl. 13, fig. 75.

Female: Head rounded, rostrum bifid, the prongs short and hooked (Pl. 9, fig. 19). Cephalothorax of 5 segments, abdomen of three, genital segment five times as long as second (Pl. 11, fig. 42), anal three times as long as second; furca symmetrical, rami about twice as long as broad. Anterior antennae 25-jointed, extending beyond furca for one-fourth their length. Inner ramus of posterior antenna much longer than outer; mandible biramous, blade (Pl. 12, fig. 57) long, with three teeth; first outer marginal lobe of maxilla with nine bristles, first inner marginal with eleven, outer ramus with two, second basal plus inner ramus with one; bristles of maxillipeds with characteristic armature. Swimming feet not unusual, outer marginal bristle of first joint of outer ramus of first foot extending beyond distal end of terminal joint (Pl. 12, fig. 63). Rami of fifth feet 3-jointed, terminal joint of outer ramus with two outer marginals and three inner marginals; outer marginal of second basal very long and slender (Pl. 13, fig. 75).

Length: Female, 6.8 mm.

Coloration: Translucent, without pigment, except for brown in the mouth region.

Occurrence: One female, Coll. 1030. Type in the collection of the University of California.

Genus **Arietellus** Giesbrecht.

Arietellus, Giesbrecht ('92), p. 66, 415; ('98), p. 124.
Arietellus, Esterly (:05), p. 189.

Arietellus major n. sp.

Pl. 9, fig. 17; pl. 11, figs. 43, 44; pl. 12, fig. 56; pl. 13, fig. 80.

Female: The head, in lateral view, is prolonged into a blunt process (Pl. 9, fig. 17); sides of last thoracic segment rounded, but with a blunt projection in the middle of the posterior border (Pl. 11, fig. 43). Abdomen and furca symmetrical (Pl. 11, fig. 44), genital segment with a very slight ventral convexity, as long as anal segment and nearly as long as the second and third together. Furcal rami two and one-fourth times as long as broad. Anterior antennae 20-jointed, not as long as the cephalothorax; mouth parts and swimming feet as in *A. setosus* Giesbrecht. Fifth feet of the same general shape as in *A. setosus*, but the terminal spine of the outer ramus is much shorter, and curved (Pl. 13, fig. 80).

Length: Female, 6.2 mm.

Coloration: Slight reddish tinge to mouth parts, otherwise translucent.

Occurrence: One female, on the San Clemente trip. Type in the collection of the University of California.

Arietellus major is readily distinguishable from *A. setosus* Giesbrecht by the shape of the head and the fifth feet.

Family PONTELLIDAE.

Genus **Labidocera** Lubbock.

Labidocera, Giesbrecht ('92), p. 70, 444; ('98), p. 132.
Labidocera, Esterly (:05), p. 199.
Labidocera, Wheeler, ('99), p. 178.

Labidocera jollae n. sp.

Pl. 9, figs. 22, 23; pl. 12, figs. 50, 51, 53; pl. 14, figs. 89, 91.

Male: Head with lateral hooks (Pl. 9, fig. 22); last thoracic segment symmetrical (Pl. 12, fig. 53), ending in rather sharp points. Rostrum seemingly asymmetrical (Pl. 9, fig. 23), the left prong being very long and sharp, the right short and stout. Genital segment of abdomen longer than any of the others, second

and third of equal lengths; furcal blades four times as long as broad (Pl. 12, fig. 53). The left anterior antenna is as long as the cephalothorax exclusive of the last segment. Fifth feet: the right (Pl. 14, fig. 91) slender and comparatively simple in structure, terminal joint long and curved, the preceding one with a stout process on the inner margin; left foot (Pl. 14, fig. 89) with two teeth on the terminal joint.

Female: Head as in male, rostrum symmetrical; last thoracic segment, abdomen, and furca asymmetrical, the thorax ending on each side in pointed wing-like projections (Pl. 12, figs. 50, 51). Anterior antennae reaching to the last thoracic segment. Fifth feet simple, inner ramus rudimentary, outer with three apical teeth and one in the middle of the outer border.

Length: Male, 2.4 mm. Female, 2.6 mm.

Coloration: Slight greenish hue when alive; colorless in formalin.

Occurrence: One male in the cove of La Jolla, January 2, 1906, 7 p.m. One female was taken on the surface three and one-half miles from La Jolla, June 26, 1905. Types in the collection of the University of California.

The structure in the fifth feet in this species places it near *L. nerii* Kroyer, but the lateral hooks on the head make it distinct from the latter. In the possession of these hooks it approaches *L. wollastoni* Lubbock and *L. kroyeri* Brady, but differs from the former species in the structure of the fifth feet, and from the latter in the last thoracic segment. The peculiar asymmetry of the rostrum in the male, if not an individual deformity, is also a distinct character.

Genus **Pontellopsis** Brady.

Pontellopsis (part), Brady ('83), pp. 85, 87.
Monops, Giesbrecht ('92), p. 72, 486.
Monops, Wheeler ('99), p. 182.
Pontellopsis, Giesbrecht ('98), p. 145.

Head without lateral hooks, asymmetrical in male, and without dorsal or ventral eye-lenses. The ventral eye ranges in shape from flatly convex to spherical; rostral filaments long and delicate. Fourth and fifth thoracic segments fused, lateral angles

ending usually in sharp points, asymmetrical in the male. Abdomen of female of one or two segments; that of male of five; asymmetrical in both sexes. Anterior antennae of female 16-jointed; grasping antenna with enlarged and broadened middle portion (Pl. 12, fig. 59), terminal portion 2-jointed. Mandibular blade with blunt teeth; in the maxilla the second basal is hardly half as long as the second lobe of the inner margin. The distal bristles of the second maxilliped are long compared with the proximal ones and sparsely spinose. Second maxilliped 5-jointed. Inner ramus of first foot 3-jointed, that of second to fourth feet 2-jointed. Fifth feet as in *Labidocera*, but the left foot in the male has not even a rudimentary inner ramus.

Pontellopsis occidentalis n. sp.

Pl. 11, figs. 47, 48, 49; pl. 12, fig. 59; pl. 13, fig. 68; pl. 14, figs. 92, 96.

Female: The last thoracic segment ends in long points which extend back farther than the middle of the abdomen (Pl. 11, fig. 48); abdomen very obscurely 2-segmented, asymmetrical, being prolonged on the right side. Left furcal blade broader than the right, but no longer. There is a knob-like protuberance on the right side of the genital segment at the posterior border. The anterior antennae extend back to the suture between the second and third thoracic segments. The fifth foot is biramous, each ramus 1-jointed (Pl. 13, fig. 68); the outer ramus ends in two teeth of about equal length, and there is a tooth on the inner margin which is twice as long as the apical ones and much heavier. The outer margin of the ramus has three short spines; the inner ramus is bifid at the tip, and half as long as the outer ramus.

Male: The last thoracic segment ends in long points as in the female, but is not quite symmetrical, since the point on the right side is longer and bent slightly toward the left (Pl. 11, fig. 49). The abdomen is not very asymmetrical; the first and second segments have spines on the right side (Pl. 11, fig. 47). Fifth foot: Right foot in the form of a forceps (Pl. 14, fig. 96); first joint of outer ramus with a heavy, blunt process. The terminal joint of the left foot (Pl. 14, fig. 92) is thickly pubescent on the inner

margin. The second basal of each foot is without a plumose bristle.

Length: Female, 3.8 mm. Male, 3 mm.

Coloration: The entire animal is bluish, and the color extends into the bristles of the appendages.

Occurrence: The animals were rather common during the summer and were always taken at the surface. Types in the collection of the University of California.

The male may be distinguished from other species of the genus by the shape of the fifth foot and the abdomen. The species resembles *P. villosa* Brady, but the thorax and appendages are not pubescent; the other characters mentioned are also differential.

Calanus robustior Giesbrecht.

Pl. 14, fig. 81.

The female was reported previously (Esterly, :05, p. 129). The male was taken in Coll. 1030.

Length: 3.3 mm.

Coloration: Opaque, and without pigment; general appearance is whitish.

The specimen placed here has two or three small bristles on the inner ramus of the left fifth foot (Pl. 14, fig. 81), but otherwise conforms to Giesbrecht's description.

Heterorhabdus longicornis Giesbrecht.

Pl. 13, fig. 74.

The male was taken previous to the past summer (Esterly, :05, p. 186). One female was obtained in Coll. 1030.

Length: Female, 3.4 mm.

Coloration: Translucent, without pigment.

Heterorhabdus spinifrons Claus.

Pl. 14, fig. 93.

The female was obtained in 1904 (Esterly, :05, p. 183), and a male was taken in 1905 in Coll. 1030.

Length: Female, 3 mm.

Coloration: Translucent and without pigment.

APPENDIX.

List of species which have been described since 1897 for the genera dealt with in this paper:—

Augaptilus fungifera, Steuer (:04), p. 597.
gibbus, Wolfenden (:04), p. 122.
magnus, Wolfenden (:04), p. 122.
zetesios, Wolfenden (:02), p. 369, pl. 3.

Euchaeta antarcticus, Giesbrecht (:03), p. 21, pl. 3, figs. 1-8.
austrina, Giesbrecht (:03), p. 22, pl. 3, figs. 9-16.
glacialis (Hansen), Sars (:02a), p. 40, pl. 27 (= *E. norvegica,* part).
oceana, Thompson (:03), p. 19, pl. 2, figs. 1-9.

Euchirella carinata, Wolfenden (:02), p. 366; (:04), p. 115.
curticauda var. *atlantica,* Wolfenden (:04), p. 116.

Gaetanus caudani (new?), Wolfenden (:04), p. 125, pl. 9, figs. 20, 21, 22.
denticulatus, Aurivillius ('98), p. 30, figs. 1, 2, 3.
major, Wolfenden (:04), p. 114, pl. 9, figs. 7, 8.

Labidocera aestiva, Wheeler ('99), p. 178, fig. 16.
trispinosa, Esterly (:05), p. 200, fig. 48.
kroyeri var. *gallensis,* Thompson and Scott (:03), p. 251, pl. 2, figs. 8, 9.
kroyeri var. *stylifera,* Thompson and Scott (:03), p. 252, pl. 2, figs. 8, 9.
pectinata, Thompson and Scott (:03), p. 252, pl. 2, figs. 10-14.

Metridia gerlacheri, Giesbrecht (:03), p. 37, pl. 5, figs. 6-14.
normani female, Wolfenden (:04), p. 125, pl. 9, figs. 39, 40.
?venusta male, Thompson (:03), p. 24, pl. 6, figs. 1, 2.
Pontellopsis herdmani, Thompson and Scott (:03), p. 253, pl. 2, figs. 15-17.

Scolecithrix atlanticus, Wolfenden (:04), p. 119, pl. 9, figs. 5, 6.
brevicornis, Sars (:00), p. 46, pl. 10. Considered as *Amallophora brevicornis,* Sars (:02b), p. 53.
?chelifer, Thompson (:03), p. 21, pl. 5, figs. 1-9.
glacialis, Giesbrecht (:03), p. 25, pl. 4, figs. 1-7.
magna, Sars (:02b), p. 55, pls. 34-35. (Sars considers the species as belonging to *Amallophora.*)
pacifica, Esterly (:05), p. 168, fig. 30.
securifrons, Wolfenden (:04), p. 168, fig. 30. (Held by Wolfenden to belong to *Lophothrix*).
similis, Wolfenden (:04), p. 119, pl. 9, figs. 5, 6.
subdentata, Esterly (:05), p. 167, fig. 29.

Spinocalanus abyssalis male, Sars (:03), p. 157, suppl. pl. 3.
longicornis, Sars (:00), p. 75, pl. 22; (:02a), p. 22, pl. 12. (= *S. abyssalis* Giesbrecht.)
magnus, Wolfenden (:04), p. 118.

Xanthocalanus atlanticus, Wolfenden (:04), p. 119, pl. 9, figs. 24, 25, 33.
borealis, Sars (:00), p. 49, pl. 11.
cristatus, Wolfenden (:04), p. 119, pl. 9, figs. 18, 19.
fragilis, Aurivillius ('98), p. 23, figs. 4, 5, 6.
giesbrechti, Thompson (:03), p. 22, pl. 4, figs. 1-9.
simplex, Aurivillius ('98), p. 33, fig. 7.
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DESCRIPTION OF PLATES.

PLATE IX.

Fig. 1. *Xanthocalanus similis* n. sp. Female, head from side, × 40.

Fig. 2. *Chirundina streetsi* Giesbrecht. Female, head from side, × 40.

Fig. 3. *Gaetanus unicornis* n. sp. Female, head from side, × 40.

Fig. 4. *Gaetanus brevicornis* n. sp. Female, head from side, × 40.

Fig. 5. *Gaetanus clarus* n. sp. Male, head from side, × 40.

Fig. 6. *Euchirella curticauda* Giesbrecht. Female, head from side, × 70.

Fig. 7. *Euchaeta dubia* n. sp. Male, head from side, × 40.

Fig. 8. *Euchaeta spinifera* n. sp. Male, head from side, × 70.

Fig. 9. *Euchaeta propinqua* n. sp. Female, head from side, × 70.

Fig. 10. *Euchaeta tonsa* Giesbrecht. Female, head from side, × 70.

Fig. 11. *Euchaeta californica* n. sp. Female, head from side, × 70.

Fig. 12. *Euchaeta tenuis* n. sp. Female, head from side, × 70.

Fig. 13. *Scolecithrix magna* (Scott). Female, head from side, × 70.

Fig. 14. *Scolecithrix frontalis* Giesbrecht. Female, head from side, × 40.

Fig. 15. *Metridia atra* n. sp. Male, head from side, × 40.

Fig. 16. *Metridia atra* n. sp. Male, head and basals of left anterior antenna, dorsal, × 25.

Fig. 17. *Arietellus major* n. sp. Female, head from side, × 70.

Fig. 18. *Scolecithrix inornata* n. sp. Female, head from side, × 40.

Fig. 19. *Augaptilus rostratus* n. sp. Female, head from side, × 40.

Fig. 20. *Metridia ignota* n. sp. Female, head from side, × 70.

Fig. 21. *Disseta grandis* n. sp. Female, head from side, × 40.

Fig. 22. *Labidocera jollae* n. sp. Male, head dorsal, × 40.

Fig. 23. *Labidocera jollae* n. sp. Male, head from side, × 70.

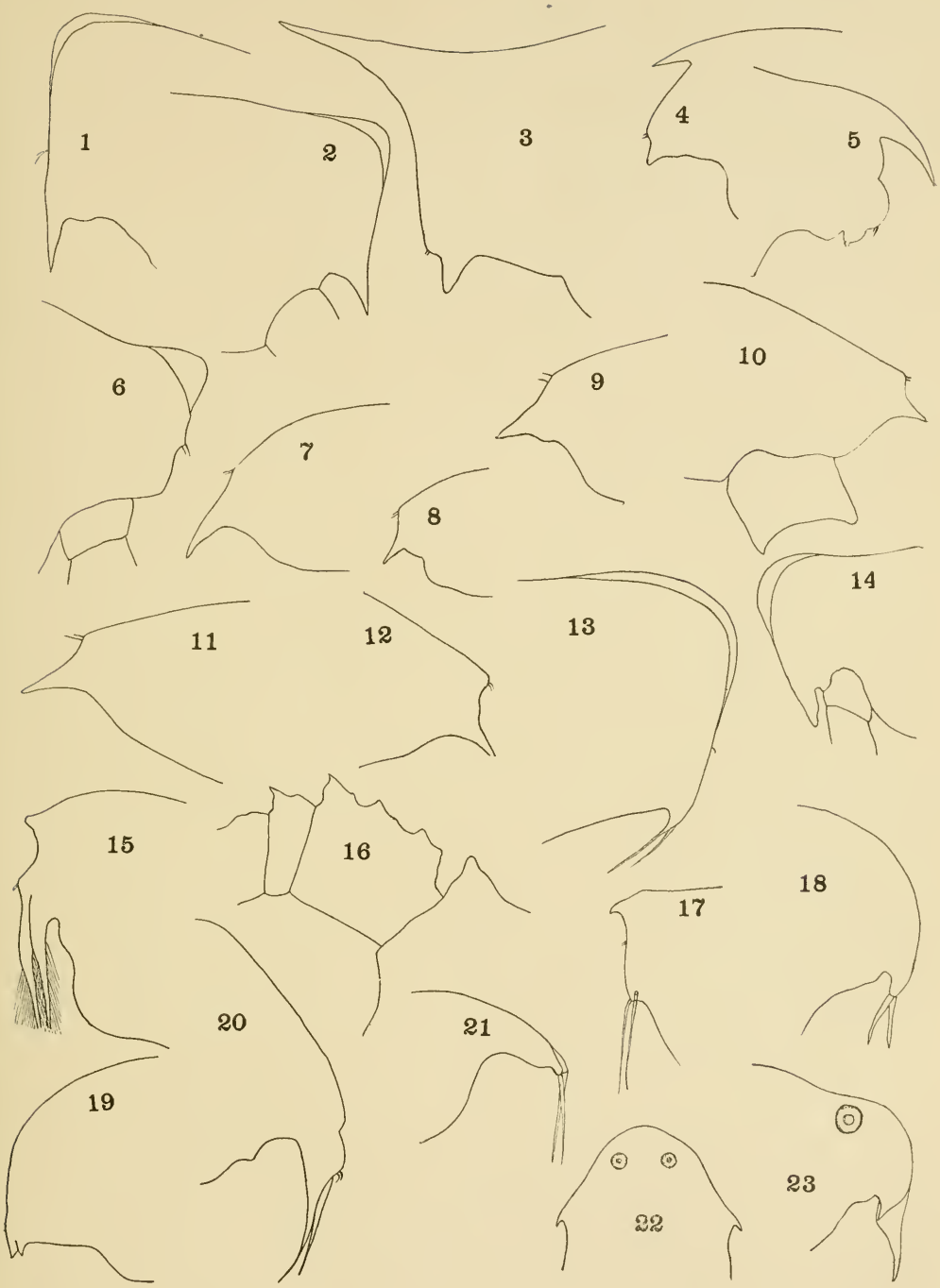
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PLATE X.

Fig. 24. *Xanthocalanus similis* n. sp. Female, last thoracic segment lateral, × 40.

Fig. 25. *Gaetanus unicornis* n. sp. Female, last thoracic segment and abdomen lateral, × 40.

Fig. 26. *Euchaeta californica* n. sp. Female, genital segment ventral, × 40.

Fig. 27. *Euchirella curticauda* Giesbrecht. Female, abdomen and part of last thoracic segment lateral, × 70.

Fig. 28. *Chirundina streetsi* Giesbrecht. Female, abdomen and last thoracic segment ventral, × 40.

Fig. 29. *Euchaeta tenuis* n. sp. Female, genital and last thoracic segments lateral, × 40.

Fig. 30. *Euchaeta propinqua* n. sp. Female, genital segment ventral, × 40.

Fig. 31. *Euchaeta tenuis* n. sp. Female, genital segment ventral, × 40.

Fig. 32. *Euchaeta tonsa* Giesbrecht. Female, genital and last thoracic segments lateral, × 40.

Fig. 33. *Euchaeta propinqua* n. sp. Female, genital and last thoracic segments lateral, × 40.

Fig. 34. *Euchaeta californica* n. sp. Female, genital and last thoracic segments lateral, × 40.

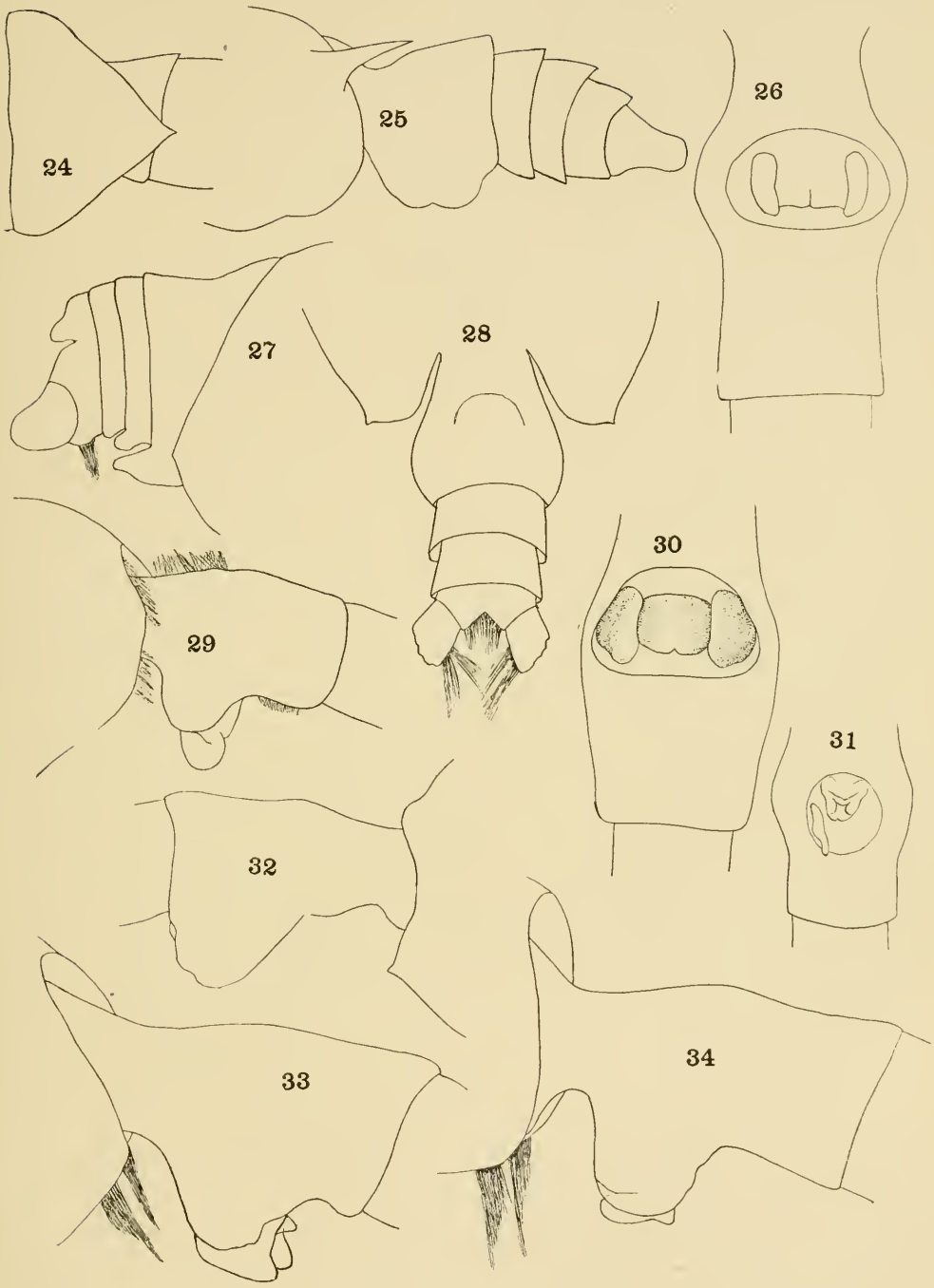
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PLATE XI.

Fig. 35. *Euchaeta spinifera* n. sp. Male, last thoracic segment lateral, × 40.

Fig. 36. *Euchaeta dubia* n. sp. Male, genital and last thoracic segments lateral, × 40.

Fig. 37. *Scolecithrix inornata* n. sp. Female, abdomen and last thoracic segment lateral, × 40.

Fig. 38. *Scolecithrix magna* (Scott). Female, outline of last thoracic segment lateral, × 70.

Fig. 39. *Metridia atra* n. sp. Male, furca and anal segment dorsal, × 25.

Fig. 40. *Metridia atra* n. sp. Male, furca and anal segment lateral, × 70.

Fig. 41. *Metridia princeps* Giesbrecht. Male, furca and anal segment dorsal, × 25.

Fig. 42. *Augaptilus rostratus* n. sp. Female, abdomen lateral × 40.

Fig. 43. *Arietellus major* n. sp. Female, abdomen and last thoracic segments lateral, × 25.

Fig. 44. *Arietellus major* n. sp. Female, abdomen ventral, × 25.

Fig. 45. *Disseta grandis* n. sp. Male, abdomen and last thoracic segment lateral, × 25.

Fig. 46. *Disseta grandis* n sp. Female, abdomen ventral, × 25.

Fig. 47. *Pontellopsis occidentalis* n. sp. Male, abdomen ventral, × 40.

Fig. 48. *Pontellopsis occidentalis* n sp. Female, abdomen and last thoracic segment dorsal, × 40.

Fig. 49. *Pontellopsis occidentalis* n. sp. Male, last thoracic segment dorsal, × 40.

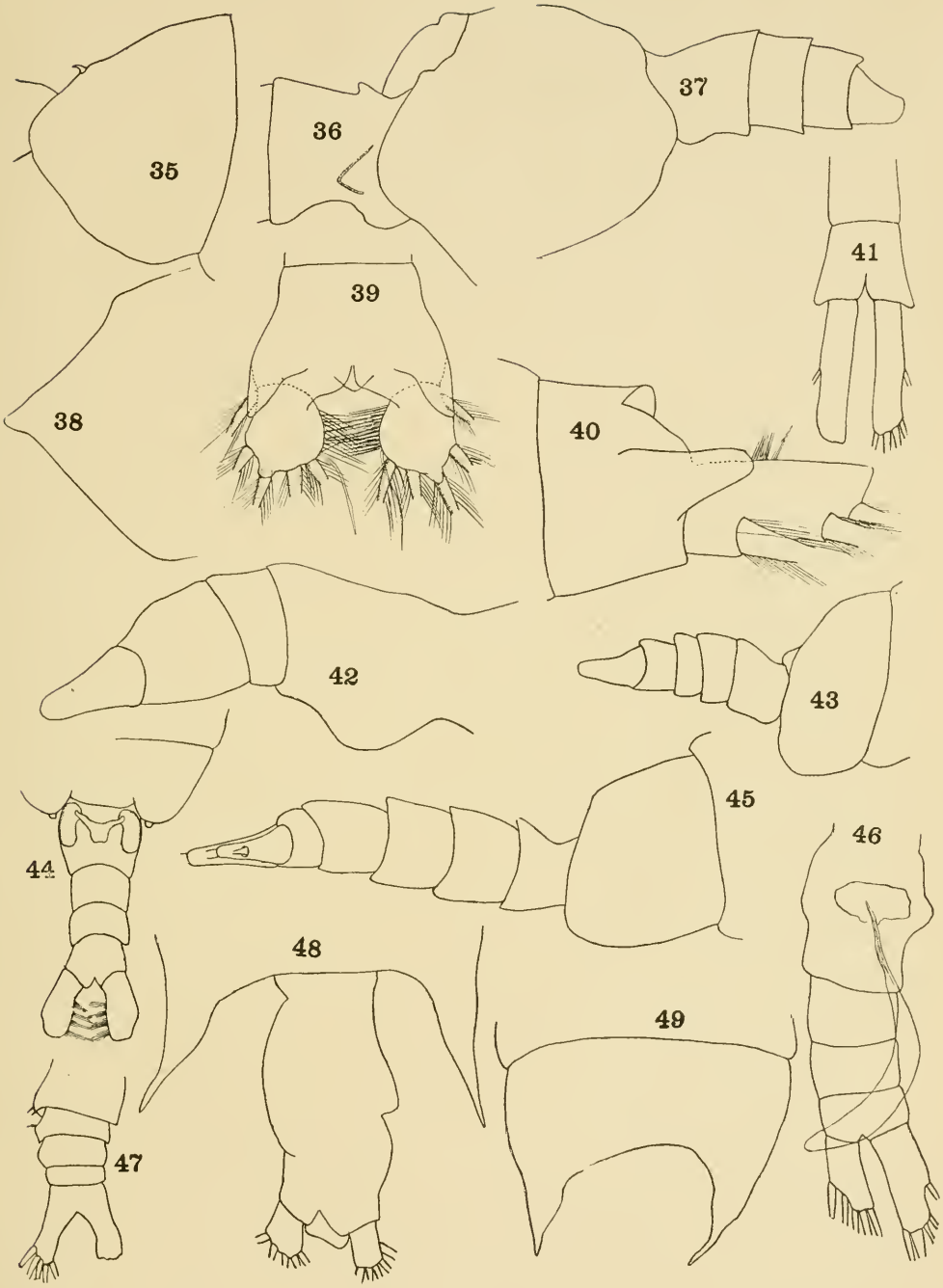
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PLATE XII.

Fig. 50. *Labidocera jollae* n. sp. Female, abdomen and part of thorax dorsal, × 70.

Fig. 51. *Labidocera jollae* n. sp. Female, abdomen and last thoracic segment lateral, × 40.

Fig. 52. *Scolecithrix magna* (Scott). Female, outer ramus of first foot, × 70.

Fig. 53. *Labidocera jollae* n. sp. Male, abdomen and last thoracic segment dorsal, × 70.

Fig. 54. *Gaetanus unicornis* n. sp. Female, first basal of posterior maxilliped, × 70.

Fig. 55. *Gaetanus brevicornis* n. sp. Female, first basal of posterior maxilliped, × 70.

Fig. 56. *Arietellus major* n. sp. Female, blade of mandible, × 70.

Fig. 57. *Augaptilus rostratus* n. sp. Female, blade of mandible, × 70.

Fig. 58. *Chirundina streetsi* Giesbrecht. Male, first foot, × 70. Bristles not shown on inner ramus.

Fig. 59. *Pontellopsis occidentalis* n. sp. Male, middle portion of grasping antenna, × 40. Bristles and aesthetasks not shown.

Fig. 60. *Xanthocalanus similis* n. sp. Female, distal portion of anterior maxilliped showing the sensory appendages, × 70.

Fig. 61. *Xanthocalanus similis* n. sp. First foot, × 70.

Fig. 62. *Euchirella curticauda* Giesbrecht. Female, posterior antenna, × 70. Bristles not shown.

Fig. 63. *Augaptilus rostratus* n. sp. Female, first foot, × 70.

Fig. 64. *Scolecithrix magna* (Scott). Female, second foot, × 70.

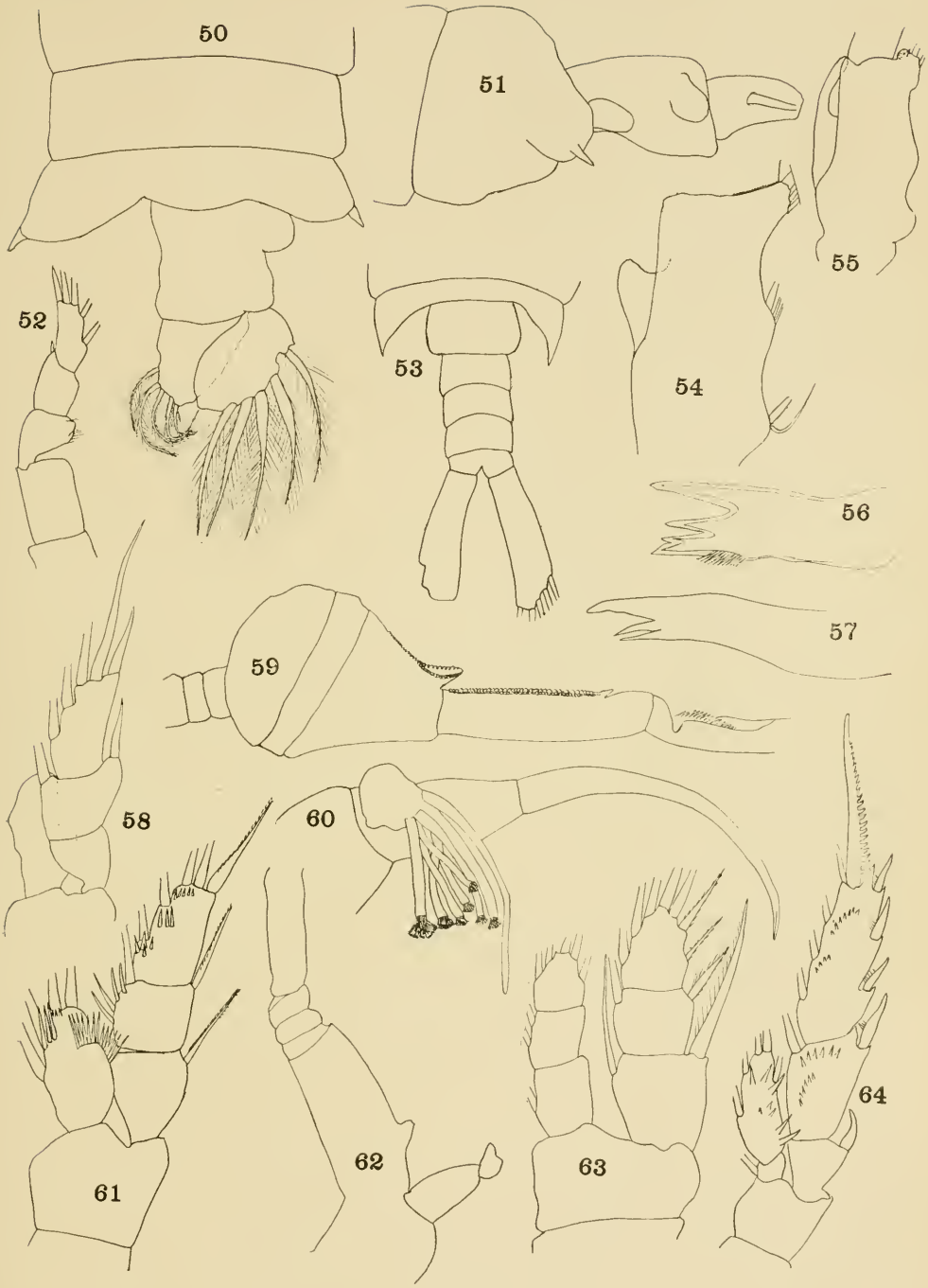
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PLATE XIII.

Fig. 65. *Scolecithrix inornata* n. sp. Female, fourth foot, × 40.

Fig. 66. *Euchaeta dubia* n. sp. Male, distal portion of second joint, and third joint of outer ramus of second foot, × 40.

Fig. 67. *Euchirella curticauda* Giesbrecht. Female, distal portion of inner margin of first basal of fourth foot, × 190.

Fig. 68. *Pontellopsis occidentalis* n. sp. Female, fifth foot, × 70.

Fig. 69. *Disseta grandis* n. sp. Female, fifth foot, × 40.

Fig. 70. *Scolecithrix frontalis* Giesbrecht. Female, fifth feet, × 70.

Fig. 71. *Xanthocalanus similis* n. sp. Female, third foot, × 40.

Fig. 72. *Scolecithrix magna* (Scott). Female, fifth foot, × 190.

Fig. 73. *Scolecithrix inornata* n. sp. Female, fifth feet, × 40.

Fig. 74. *Heterornabaus longicornis* Giesbrecht. Female, fifth foot, × 70.

Fig. 75. *Augaptilus rostratus* n. sp. Female, outer ramus of fifth foot, × 70.

Fig. 76. *Gaetanus unicornis* n. sp. Female, distal portion of inner margin of first basal of fourth foot, × 190.

Fig. 77. *Xanthocalanus similis* n. sp. Female, fifth foot, × 70.

Fig. 78. *Metridia atra* n. sp. Female, fifth foot, × 40.

Fig. 79. *Metridia princeps* Giesbrecht. Female, fifth foot, × 70.

Fig. 80. *Arietellus major* n. sp. Female, fifth foot, × 70.

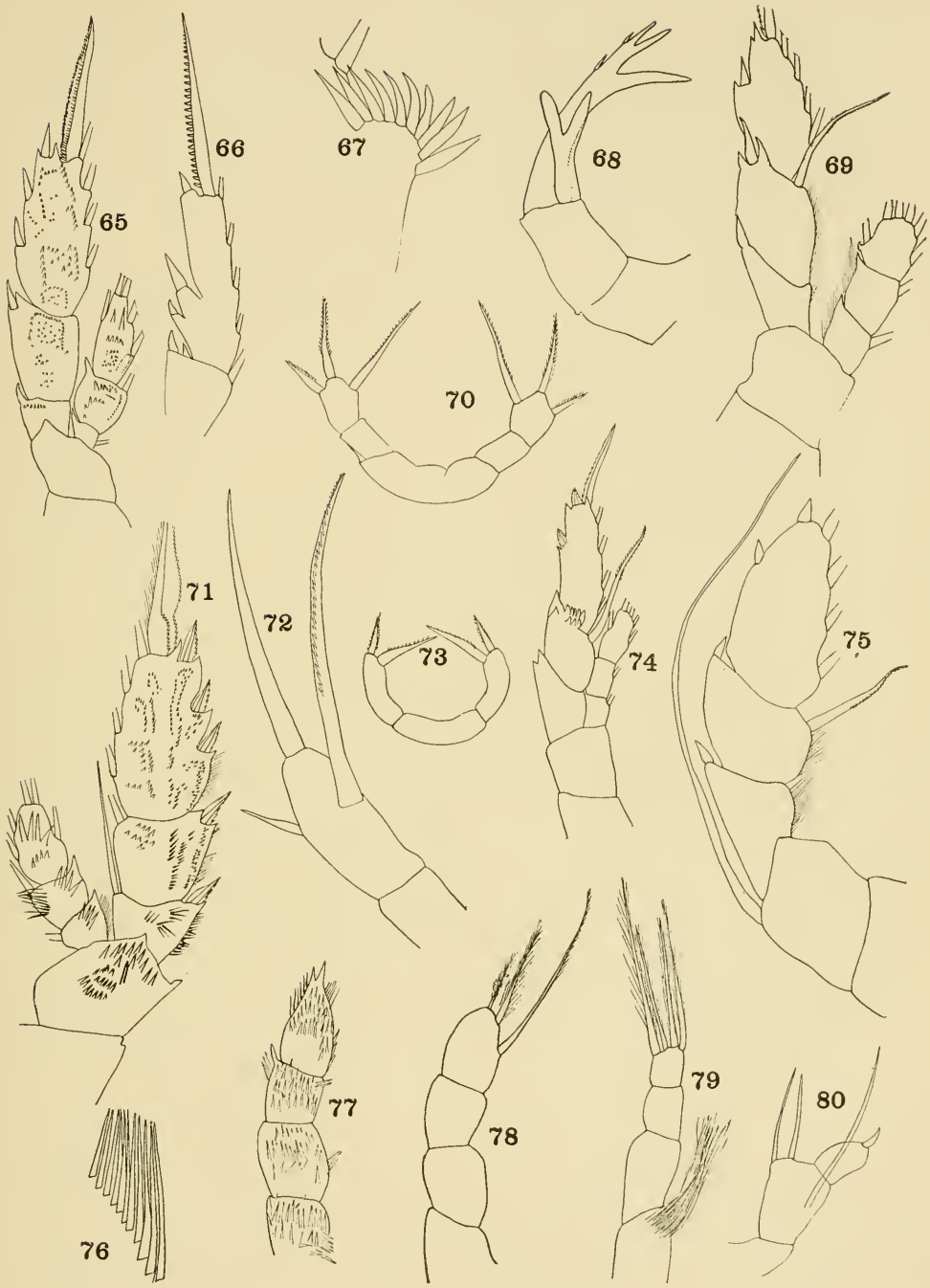
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PLATE XIV.

Fig. 81. *Calanus robustior* Giesbrecht. Male, left fifth foot, × 70.

Figs. 82, 83. *Euchaeta spinifera* n. sp. Male, distal portion of second joint of outer ramus of left fifth foot, × 70.

Fig. 84. *Euchaeta dubia* n. sp. Male, fifth pair of feet, × 25.

Fig. 85. *Euchaeta dubia* n. sp. Male, distal portion of second joint of outer ramus of left fifth foot, × 70.

Fig. 86. *Chirundina streetsi* Giesbrecht. Male, right fifth foot, × 40.

Fig. 87. *Chirundina streetsi* Giesbrecht. Male, left fifth foot, × 40.

Fig. 88. *Disseta grandis* n. sp. Male, left fifth foot, × 40.

Fig. 89. *Labidocera jollae* n. sp. Male, left fifth foot, × 70.

Fig. 90. *Gaetanus clarus* n. sp. Male, fifth feet, × 40. Right foot at left of figure.

Fig. 91. *Labidocera jollae* n. sp. Male, right fifth foot, × 40.

Fig. 92. *Pontellopsis occidentalis* n. sp. Male, left foot of fifth pair, × 40.

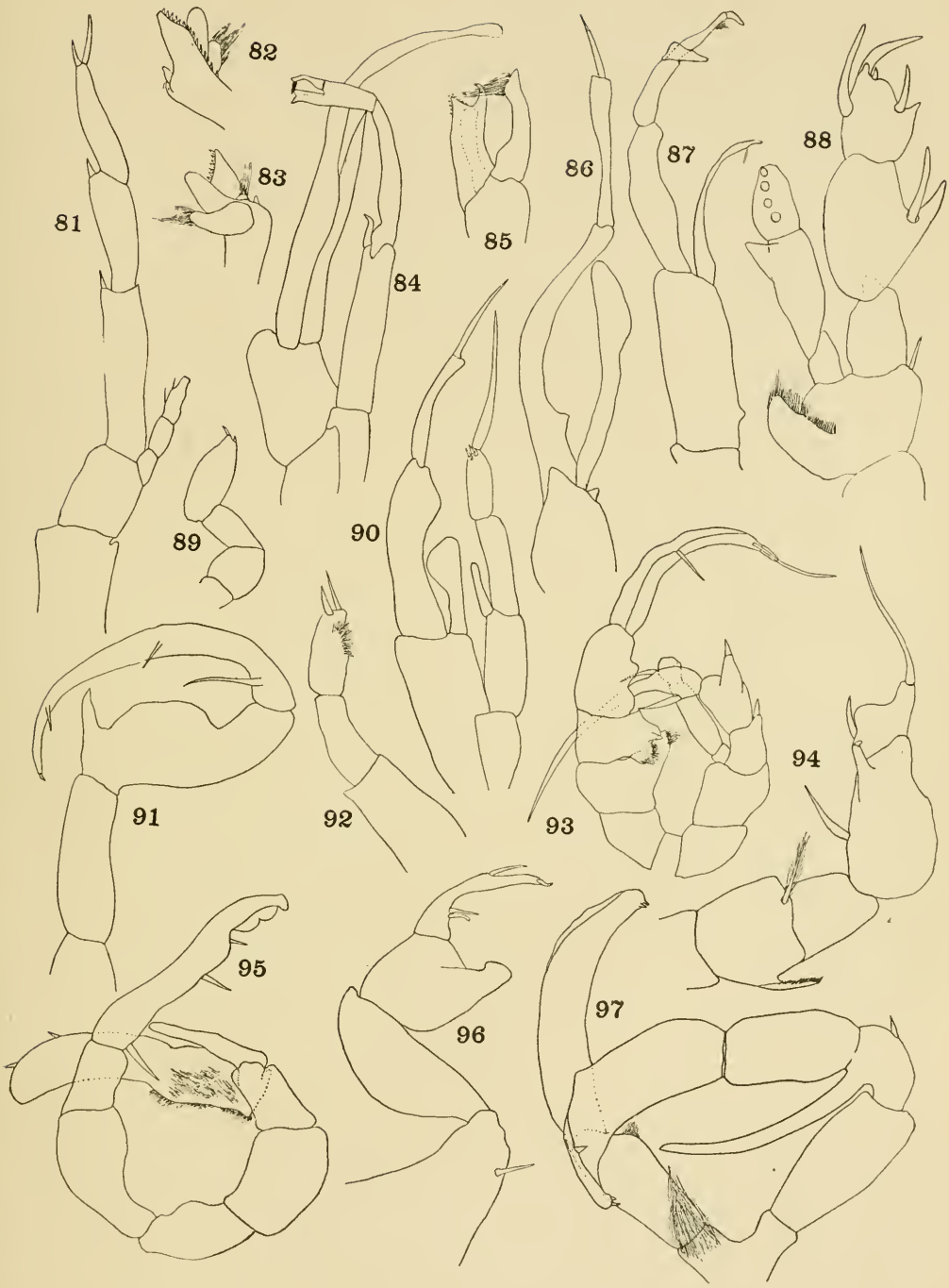
Fig. 93. *Heterorhabdus spinifons* Giesbrecht. Male, fifth feet, × 40.

Fig. 94. *Disseta grandis* n. sp. Male, right fifth foot, × 40.

Fig. 95. *Metridia atra* n. sp. Male, fifth feet, × 25.

Fig. 96. *Pontellopsis occidentalis* n. sp. Male, right fifth foot, × 40.

Fig. 97. *Metridia princeps* Giesbrecht. Male, fifth feet, × 70.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BY

CHARLES ATWOOD KOFOID

7.—A DISCUSSION OF SPECIES CHARACTERS IN TRIPOSOLENIA

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XIII.

DINOFLAGELLATA OF THE SAN DIEGO REGION, II. ON *TRIPOSOLENIA*, A NEW GENUS OF THE DINOPHYSIDAE.

BY
CHARLES ATWOOD KOFOID.

The plankton taken in deeper waters off San Diego during the past four years has contained a number of individuals of species of the *Dinophysidae* related to *Amphisolenia*. The relative variety of the forms and their less accessible habitat probably account for the fact that they have not been observed by other investigators, though it is not improbable that Schütt's ('93) *Amphisolenia tripos* (*nomen nudum*) is a member of this genus.

The five forms here described, together with three others described elsewhere (Kofoid :06), constitute a compact group of related species having in common a set of distinctive characters which delimit them from the known species of *Amphisolenia*, to which genus they are all more closely related than to any other of the *Dinophysidae*.

Their relationship to *Amphisolenia* is indicated by the differentiation of the body into the following regions: An expanded, rounded, or flattened head girdled by the transverse furrow, an elongated slender neck terminating posteriorly in the expanded cytopharynx, an expanded midbody containing the nucleus, and

an antapical prolongation. The distinctive characters of the genus are (1) the form of the midbody, which is strongly compressed laterally, and (2) the presence of a pair of nearly equal and usually nearly symmetrical antapical horns, both of which arise from the midbody.

The *axial relations* in *Triposolenia* differ from those of other *Dinophysidae* owing to the obliquity of the neck and to the dorso-ventral asymmetry of the antapicals. In *Dinophysis* and *Phalacroma* the main (antero-posterior) axis passes through the center of the epitheca, the center of the hypotheca and the antapex in nearly a straight line. The bilateral asymmetry in these genera, if any, is slight. In *Amphisolenia* the main axis is straight, or nearly so, except in some species in the distal part of the single antapical horn. This is often bent to the left distally or curved in the dorso-ventral plane in bifurcated or branched species such as *A. thrinax* and *A. bifurcata*. The epitheca, neck, midbody, and a large part of the antapical horn lie in the straight line of the main axis. The species of the genus are thus predominantly linear in type.

In *Triposolenia*, however, the main axis is not a straight line, for there is both bilateral and dorso-ventral asymmetry. Assuming the axis of the midbody as a base of reference because of its relation to the balanced antapicals and to the plane of the girdle, we find that the anterior process is always displaced ventrally, in *T. ramiciformis* and *T. exilis* to the very margin of the midbody, in other species to a very slight extent. Its axis, moreover, is always inclined 10°–20° ventrally from the main axis. The neck, on the other hand, is displaced dorsally on the anterior process and is inclined dorsally from 10°–35° from the axis of the midbody and is in addition not infrequently curved in the dorsal direction. The plane of the girdle is nearly perpendicular to the axis of the midbody, at least more nearly so than to the axis of the neck. Presumably the axis of rotation in locomotion is approximately perpendicular to the plane of the girdle and is therefore coincident with or at least nearly parallel to the axis of the midbody.

The antapical extensions of the body among the *Dinophysidae* are feebly developed except in *Amphisolenia* and *Triposolenia*.

In *Phalacroma, Ornithocercus,* and *Histioneis* they consist merely of reticular extensions from the thecal wall. In the two genera first named, however, the thecal wall itself and the protoplasmic contents are prolonged posteriorly in well defined antapical horns, one in *Amphisolenia* and two in *Triposolenia.*

The pair of processes in *Triposolenia* exhibits certain constant relations which give to the symmetry of the organism a tripartite character that is unique among the *Dinophysidae*, though forms exhibiting a superficial resemblance are seen in the genus *Ceratium* and in *Peridinium.* In both of these genera, however, the antapical horns are right and left, that is, the bifurcation is bilateral, while in *Triposolenia* the horns are dorsal and ventral, and the bifurcation is sagittal. The only other instances of sagittal bifurcation among the Dinoflagellates are found also in the family *Dinophysidae*, in *Amphisolenia bifurcata* (Murray and Whitting, '99), *A. thrinax* (Schütt, '93), and *A. quinquecauda,* and in *Phalacroma ultima.* The bifurcation is, however, but feebly expressed in these species as compared with its development in *Triposolenia.* The tripartite character of this genus is shown in the proportionate development of the anterior process and the pair of antapical horns. The distance of the apex of the epitheca from the center of the midbody is approximately equal to that of the antapices of the horns from the same point. The proportionate development of the two antapicals and the anterior process is equally evident in the short-horned forms of the San Diego region, and the long-horned ones of the warmer waters of the tropics. Elongation of the anterior process is coincident with elongation of the antapicals and is present throughout all types of curvature and origin of the horns. In species with antapicals arising from the posterior angles of the midbody this equality is less marked than in those with the pendant midbody, the anterior process being a trifle shorter in the first named group. The ventral horn is also a little longer than the dorsal in all the species, an asymmetry which finds a parallel in the uniformly shorter right horn of the bifurcated species of *Ceratium* and *Peridinium.* The ventral antapical of *Amphisolenia* and the right one of *Ceratium* and *Peridinium* lie on the side nearest to the longitudinal flagellum and to the axis of rotation and of locomotion. Elonga-

tion in the axis of locomotion is a common phenomenon among organisms. It may be that the dorsal deflection of the head balances the deficiency in the length of the dorsal antapical.

The balanced relationship of the two antapicals to each other and to the midbody is as striking as the similar relationship of the anteriorly deflected horns of the long-horned forms of *Ceratium* such as *C. vultur* Cleve, and *C. patentissimum* Ost. and Schm. This balance is shown in their approximately equal development and similar spread from the axis and in the correspondence in the reversed curvatures of the two horns. This balance is only approximate, however, appearing at its highest development in *T. truncata* and *T. bicornis* and progressively encroached upon in *T. fatula* and *T. ambulatrix*, where the dorsal horn is deflected dorsally without corresponding ventral deflection of the ventral horn. It is noteworthy that in both of these species the dorsal deflection of the anterior process is decreased as if to counterbalance the increased dorsal deflection of the dorsal antapical.

This coördination in the matter of the proportionate development of the three processes from the midbody and the balanced relationship of the antapicals throughout the species of the genus suggests an important function in orientation for flotation and locomotion.

The body as in other *Dinophysidae* is composed of two valves, a right and left, which separate along a sagittal suture line. The suture in *Triposolenia* is not structurally marked except by a faint line, or a few scattered pores along the ventral side of the neck or in the tubercles on the major flexures of the antapicals. The *epitheca* as in *Amphisolenia* is reduced to a small dome above the girdle, while the *hypotheca* constitutes the greater part of the organism. Neither girdle plates nor suture are apparent.

The *midbody* (*mb.* Pl. 15, fig. 1) is a centrally located enlargement, strongly compressed laterally, and having a triangular, elliptical, oblong, or ovoidal outline in lateral view. Its altitude is about 0.25, its transdiameter 0.1–0.04, and its dorso-ventral diameter 0.35–0.12 of the total length. It is broadly rounded on the margins, which are three in number, an antero-dorsal, an antero-ventral, and a post-margin, the three being subequal in all

species except those with pendant midbody. The slight inequality of the sides is constant in that the antero-ventral margin is in all species the shortest and the post-margin the longest. This inequality results from the fact that the anterior process in all species has its origin on the ventral side of the axis of the midbody.

The species of *Triposolenia* fall in two distinct groups or subgenera with reference to the form of the midbody. In the *truncata* group (Subgenus *Posterocornia*) the margins of the midbody are approximately equal and the horns originate on the posterior angles. In the *ramiciformis* group (Subgenus *Ramiciformis*) the two anterior margins are very unequal, the antero-dorsal being the longer and nearly horizontal, the antero-ventral being practically obliterated, while the post-margin is extended in a pendant lobe with oblong or subrectangular outline. The nucleus and the greater part of the protoplasm of the organism is found in this pendant region.

The *anterior process* (*a.p.* Pl. 15, fig. 1) is an extension of the midbody in the antero-ventral direction at an angle of 10°–20° from the axis. Its length does not exceed and is usually less than the altitude of the midbody. It is a stout, laterally compressed process about twice as thick dorso-ventrally as the neck. It expands abruptly on the ventral side at the cytopharynx (*c'ph.* Pl. 15, fig. 2) about the flagellar pore (*f.p.* Pl. 16, fig. 6). Its point of origin in species with pendant midbody (Pl. 17, figs. 7, 8) is shifted to the ventral side so that the ventral horn and anterior process bifurcate from a common projection of the midbody.

The *neck* (*n.* Pl. 16, fig. 6) is a slender cylindrical extension of the anterior process, whose length to the base of the head is 0.8–1.75 of the altitude of the midbody. It is straight or curved dorsally, of uniform calibre throughout or constricted distally (Pl. 17, fig. 7) and is more or less, 10°–35°, deflected dorsally from the axis. It passes abruptly into the expanded head just below the posterior collar of the girdle.

The *head* (*hd.* Pl. 15, fig. 2) is composed of the epitheca and the expanded region at the end of the neck. It is encircled by the broad transverse furrow which covers nearly two-thirds of its

axial length. Its form varies much in the different species. It is laterally compressed and its transdiameter is not much greater than that of the neck. Its dorso-ventral diameter is more extended and its anterior face is rounded in most species, but concave in *T. truncata* (Pl. 16, fig. 5).

The *antapical horns* (*a.h.* Pl. 15, fig. 2) are latero-posterior extensions from the midbody, of approximately circular cross-section, and curved from a lateral direction at their origin to a posterior one distally. The dorsal horn is always a little shorter than the ventral and the two horns stand in a balanced relation to the axis of the midbody. The curvature is in some cases localized in a major flexure (*m.f.* Pl. 17, fig. 7) and in others, as in *T. truncata,* is distributed. The distal ends of the horns exhibit in lateral view in some species a slight sigmoid curvature, the antapices being deflected outward. The tips are without spinules and rounded (*T. exilis* Pl. 17, fig. 8), or truncate with dorso-ventral spinules (*T. truncata* Pl. 16, fig. 5), or with lateral spinules (*T. depressa* Pl. 16, fig. 3). In all species but *T. truncata* the outer margins of the major flexures or adjacent regions bear 2–4, rarely 1–2, or 5–7 small elevations or tubercles (*t.* Pl. 15, fig. 2), each pierced by a pore. They lie close to the sagittal suture and are conical elevations deflected posteriorly. In addition to the curvature in the dorso-ventral plane there is in all species a slight bilateral asymmetry, in that the antapical horns do not lie in the sagittal plane of the midbody but are bent to the right slightly in the middle or anterior regions and distally to the left, the dorsal horn exhibiting more of the distal curvature than the left.

The *thecal wall* in this genus, as also in most species in *Amphisolenia,* is hyaline and apparently structureless. It is of nearly uniform thickness except on concave faces of the horns, where, as in *Ceratium,* the wall is somewhat thickened, especially in the more robust individuals. Under the highest magnification the wall is very faintly and minutely spotted or flecked, as if in the incipient stages of pitting or reticulation. In but a single species, *T. truncata,* are these structures developed into plainly visible pits and reticulations. The pores are found only in the tubercles and along the ventral suture on the neck.

The *transverse furrow* (*tr.f.* Pl. 16, fig. 6) encircles the head as a wide equatorial band, which is slightly if at all impressed. Its floor is flattened in *T. bicornis* (Pl. 15, fig. 2), slightly concave in *T. depressa* (Pl. 16, fig. 3), or convex in *T. ramiciformis* (Pl. 17, fig. 7). There is no appreciable displacement distally in the furrow, that is, it does not form a spiral about the head.

The *anterior list* or collar (*a.l.* Pl. 16, fig. 6) is a flaring hyaline sheet with 12–20 equidistant ribs. There are two prominent ventral ribs at the ventral suture. The plane of both lists is oblique to the neck, being directed ventro-posteriorly, slightly beyond the perpendicular to the axis of the midbody. The anterior list flares obliquely anteriorly at an angle of 10° or more and is frequently concave posteriorly. On account of the posterior displacement of the flagellar pore the *posterior list* (*p.l.* Pl. 16, fig. 6) of the transverse furrow has an unusual form in both *Triposolenia* and *Amphisolenia.*

Instead of forming a simple circle about the girdle as in *Peridinium*, the posterior list turns abruptly posteriorly at the ventral suture and continues posteriorly along the ventral side of the neck in two parallel wings to the flagellar pore forming the pseudo-longitudinal furrow. The transverse flagellum (*tr.fl.* Pl. 16, fig. 6) runs anteriorly to the collar in this channel. The right list is not so high as the left and both rise from the thickened ridges on the neck. Posteriorly the two fins diverge to enclose the flagellar pore (*f.p.* Pl. 16, fig. 6) which lies in the pharyngeal enlargement. The height of the left fin increases at the pore and it swings in toward the median line behind the pore. In the region of the sagittal plane there is usually present a suture spine (*s.sp.* Pl. 16, fig. 6) beyond which the fin continues posteriorly for a short distance along the anterior process, and dies out within a short distance of the pore. This spine is doubtless homologous with the midspine of the ventral fin or left longitudinal list of *Dinophysis,* which Stein ('83 Taf. 20, fig. 19) has shown to be located near the suture line in *Dinophysis.* It appears from Stein's figure and from other evidence in my hands not yet published, that the ventral fin in the *Dinophysidae* lies on the left valve anterior to the midspine and *on the right valve* posterior to this spine. In some genera this spine is frequently doubled.

In any case this spine in *Triposolenia* lies near the suture and the continuation beyond the spine is also near the sagittal line and may well belong to the right valve. Not having seen *Triposolenia* in the stage of division it cannot be stated positively that the ventral fin would be parted at this spine and that the anterior and posterior moieties would go to the left and right valves respectively, but the homologies here indicated make such a division probable in this genus. The right list continues but a short distance beyond the pore, and lies on the side of the cytopharyngeal enlargement. In *Peridinium* and *Dinophysis* the longitudinal furrow lies posterior to the flagellar pore. Its homologue therefore in *Triposolenia* is the very short extension of the two lists posterior to the pore. The long anterior section may be regarded as a posterior extension of the lists of the transverse furrow affording a channel for the passage of the transverse flagellum (*tr.fl.* Pl. 16, fig. 6) from the pore to the girdle, and it may therefore be regarded as a pseudo-longitudinal furrow resulting from the migration apart of the transverse furrow and the flagellar pore and the extension of the lists in this region of migration.

The *transverse flagellum* (*tr.fl.* Pl. 16, fig. 6) arises in the flagellar pore and passes anteriorly between the longitudinal lists and encircles the head from left around to right as in other girdled Dinoflagellates. The longitudinal flagellum I have not seen in any species thus far examined. The rudimentary longitudinal furrow is suggestive of a possible reduction to a rudimentary state.

The *flagellar pore* (*f.p.* Pl. 16, fig. 6) is a large opening on the antero-ventral end of the cytopharyngeal expansion. Its left lip is somewhat higher than the right and it is therefore directed anteriorly and to the right.

The protoplasmic contents are very hyaline and coarsely granular and contain a compressed ellipsoidal nucleus (*nu.* Pl. 15, fig. 2), with a moniliform chromatin reticulum. Near the nucleus is found a pusule (*pus.* Pl. 15, fig. 2) which opens by a slender canal (*can.* Pl. 15, fig. 2) into the flagellar pore. One or more accessory pusules (*ac.pus.* Pl. 15, fig. 2) may lie near it in the plasma. Occasionally the plasma is crowded with highly refractive ellipsoidal plasmosomes of amyloid character. In many

individuals it is possible to find small irregular, pale, yellowish-green chromatophores (*chr.* Pl. 15, fig. 2) with a peripheral distribution in the cell. No species appears to possess these structures with a characteristic pattern in either form or distribution.

Reproduction, either sexual or asexual, has not been observed.

Surface temperatures of the Pacific in the San Diego region range from 14°–24° C. with a predominant temperature of 18°–20° C. throughout much of the year. At 100 fathoms the temperature has been found to range from 9.75°–13° C. No seasonal restrictions in the distribution of the species of *Triposolenia* appear in the scanty data of their occurrence in the waters off San Diego. The more common species, *T. bicornis, T. truncata,* and *T. ramiciformis,* are found in both summer and winter plankton. *T. depressa* and *T. exilis* have thus far been found very sparingly in the San Diego plankton.

Triposolenia gen. nov.

Dinophysidae with subequal valves, transverse girdle encircling a small head, neck elongated, oblique to anterior process which arises obliquely from a laterally compressed enlarged midbody. Two antapical horns, spreading, curved, approximately balanced, the dorsal a trifle shorter than the ventral. The antapical tips simple, with or without spinules or projecting tubercles or major flexures, often with a distal sinistral deflection, thecal wall structureless or pitted. Lists hyaline, ribbed, not excessively developed. Chromatophores yellowish green, if present. In oceanic plankton of warm-temperate and tropical seas in the deeper levels, rarely at the surface.

Types of the species here described are in the collections of the Zoological Department of the University of California.

Posterocornia subgen. nov. Antapicals arising from posterior part of centrally located midbody.

Ramiciformia subgen. nov. Antapicals arising from anterior part of pendant midbody.

KEY TO THE SPECIES OF TRIPOSOLENIA.

1. Antapical horns balanced, nearly symmetrical 2
1. Antapical horns asymmetrical, the dorsal one quite oblique 3
3. Neck uniform anteriorly .....*T. ambulatrix* Kofoid*
3. Neck constricted anteriorly, deflected dorsally.....*T. fatula* Kofoid*
2. Wall of midbody plainly pitted .....*T. truncata*
2. Wall of midbody not pitted 4
4. Antapical horns arising from antero-lateral angles of pendant midbody 5
4. Antapical horns arising from postero-lateral angles of midbody..... 6
5. Midbody slender, neck not very oblique to its axis .....*T. exilis*
5. Midbody stout, neck oblique to its axis .....*T. ramiciformis*
6. Midbody subtriangular in lateral view, post-margin not strongly convex, anterior margins convex .....*T. bicornis*
6. Midbody subelliptical in lateral view, post-margin strongly convex .....*T. depressa*
6. Midbody trianguar in lateral view, anterior margins concave ....*T. longicornis* Kofoid*

Triposolenia truncata sp. nov.

Pl. 10, fig. 5.

This is the most robust of the eight known species, with stout neck and stout antapical horns somewhat regularly convex outwardly, with truncate ends bearing at each terminal angle a short spinule. There are no tubercles on the antapicals. The epitheca is concave anteriorly, and the thecal wall is pitted.

The midbody is laterally compressed, subtriangular in lateral view, with the three margins nearly equal in length and nearly equally convex, the convexity of the ventral margin decreasing as it approaches the neck. The posterior margin is often a little longer than either the dorsal or ventral one, and the ventral margin a trifle shorter than the dorsal one.

The antapicals are symmetrical, their regions of major flexure and their tips being respectively equidistant from the center of the midbody. They are also approximately equal to the anterior projection, but the distance in a direct line from the center of the midbody to tip of the antapicals exceeds that to the most distant portion of the head. If, however, the distance be measured along the axis to the dorsal edge of the transverse list, the length of the anterior process equals that of the posterior ones. This

* Bull. Mus. Comp. Zool., 1906.

proportion is preserved alike in slender and in more robust individuals. There is thus apparently a correlation in the development of the three regions.

The length of the antapicals is 2.5–3.25 times the distance from the center of the midbody to their bases. Their curvature is greatest in the middle third of their course and is sometimes slightly localized in a knee, though the curvature as a whole is more uniform than in the other species. The distance between the tips is 2–2.25 times that between the bases and that between the outer margins of the knees 1.15–1.2 times that between the inner spinules of the tips. The ends are squarely truncate and each bears on the dorsal and ventral angles at the suture line a pair of slender divergent spinules not over half the diameter of the antapicals in length. Sometimes the outer spinule alone is present and is larger than usual. The dorso-ventral diameter of the antapicals at the tips is 0.5–0.7 that of their bases and the mean diameter varies from 0.1 of the total length in robust individuals to 0.06 in more slender ones. Their length varies from 1.6 to 1.8 times the diameter between their bases and 1.5 to 1.7 times the altiude of the midbody measured from the base of the anterior process to the middle of the posterior margin. The distal fourth of the antapicals is deflected slightly to the left.

The anterior prolongation consists of the head, neck, and a short extension of the midbody to the flagellar pore, the latter forming 0.3–0.4 of the total length of the process. The region of the cytopharynx is strongly protuberant ventrally, but the projection recedes more or less before its junction with the midbody. The diameter at the cytopharynx is nearly twice that of the neck.

The head is elongated, depressed, and slightly oblique, and its long axis is 0.6 of the length of the neck. The anterior face of the epitheca is quite concave, and the transverse furrow is somewhat impressed. The transverse lists are low, spreading, and the anterior one is faintly ribbed with 10–12 ribs. The longitudinal lists embrace the flagellar pore. The left one is continued beyond the pore nearly to the midbody, and has a suture spine below the pore and several accessory spines distally.

The thecal wall is pitted (pores?) profusely, but more sparingly towards the tips of the antapicals and the base of the ante-

rior process. On the neck the pits gradually widen to a coarse reticulum 2–4 meshes wide on each valve.

The nucleus is very small (in some cases observed) and is located posteriorly. There are a few irregular chromatophores, or numerous ellipsoidal ones gathered along the ventral margin.

This species, in the individuals thus far observed, is quite uniform in dimensions and proportions, except in the diameter of the three processes from the midbody. These vary considerably in thickness but less in length, thus giving to the organism different degrees of robustness with little change in the other dimensions than the diameter of the processes.

Taken in plankton from 180–30 fathoms to surface off San Diego, but always sparingly.

Dimensions: Length, 113–145 μ; distance between knees of antapicals, 83–115 μ; distance between tips of antapicals, 70–106 μ; distance from apex to middle of posterior margin of midbody, 77–97 μ; length of neck, 25–28μ; dorso-ventral diameter of midbody, 33–40 μ.

This is the type species.

Triposolenia depressa sp. nov.

Pl. 16, figs. 3, 4.

A small species with midbody elliptical in lateral view, convex margins, and antapicals of *T. bicornis* type with truncated spinulate tips.

This is the smallest of the known species of the genus and is characterized by the foreshortening of the antero-posterior axis of the midbody which gives to it an ellipsoidal form with its major axis in the dorso-ventral position. The three margins are all strongly convex and the antero-ventral is somewhat shorter than the others. The antero-posterior axis is 0.25 of the total length and 0.8 of the dorso-ventral axis of the midbody. The anterior process is very short and oblique, with well marked cytopharyngeal swelling. Its length is about 0.5 of the antero-posterior axis of the midbody. The neck is short and straight or very slightly curved dorsally toward the head, and obliquely deflected dorsally 35° from the axis of the anterior process. Its

length is about 0.25 of the total length. The head is capitate with flat or impressed furrow and low convex epitheca.

The antapicals arise from the postero-lateral regions of the *bicornis* group. The ventral is a little longer than the dorsal. They diverge postero-laterally for a short distance and then bend somewhat abruptly in a localized major flexure to a posterior direction. The greatest distance between horns is 3.5 and between the tips 3 times the altitude of the midbody. Distally they exhibit a slightly developed sigmoid flexure in lateral view. In dorso-ventral view both horns are bent to the right proximally and distally to the left, the dorsal horn having more distal curvature than the ventral. The antapical tips are truncated in dorsal or ventral view, with minute lateral terminal spinules. In lateral view the tips are somewhat rounded. There are several scattered tubercles on the outer margins of the horns.

The thecal wall is hyaline, structureless, with a few pores along the midventral line of the neck and in the tubercles of the antapicals.

A large nucleus is found in the midbody, along with principal and accessory vacuoles and a few minute scattered spheroidal chromatophores.

Dimensions: Lenth, 100–122 μ; altitude of midbody, 22–28 μ; length of antapicals, 48–70 μ.

Taken in a vertical haul from 95 fathoms off San Diego.

Triposolenia bicornis sp. nov.

Pl. 15, figs. 1, 2.

A species resembling *T. truncata* but less robust, with longer antapicals, with tuberculated major flexures and rounded tips and capitate head with convex epitheca.

The midbody resembles that of *T. truncata*, with the exception that its margins are often more convex, giving it a slightly more rotund appearance.

The antapicals arise in the same manner as in *T. truncata* and exhibit the same balanced relation with respect to each other and the same proportion to the anterior process. Both antapicals

and anterior process are shorter in robust forms and longer in the more delicate ones.

The horns have the same proximal curvature as in *T. truncata*, but the major flexure is somewhat farther removed from the midbody. Distally the horns are incurved, and then exhibit the outward curvature near the tips, which is also found in *T. ramiciformis*. There is some curvature to the left distally in both horns. There are 3–6 irregular tubercles on the outer margins of the horns below the major flexures. The ventral horn is usually a trifle longer than the dorsal one. In length the horns are 1.6–3 times the distance between their bases, or 12–40 times their width.

The anterior process is straight or concave dorsally, the projection from the midbody to the flagellar pore being one-fourth to one-third of its total length. There is usually considerable dorsal curvature in the neck and more or less protuberance of the region of the cytopharynx. The head is subcapitate, with slightly impressed furrow. The transverse lists are low and spreading with 20–24 delicate ribs. The longitudinal lists are salient at the junction with the transverse one, almost decurrent on the neck and again salient as they surround the flagellar pore. A suture spine is found in the left list just posterior to the flagellar pore. The thecal wall is structureless. Pores occur in the tubercles.

This species is the most common one in the genus at San Diego, but is never abundant as compared with many other Dinoflagellata. It varies in size, in the curvature of the antapicals and the neck and in their length and thickness. The number and location of the tubercles is also subject to considerable variation.

The nucleus is ellipsoidal and usually located near the posterior face of the midbody. An attraction sphere is found on the anterior face of the nucleus. One or two pusules are present along the ventral wall, each with efferent canal leading to the flagellar pore. The chromatophores are small, irregular, almost colorless, with superficial distribution.

Dimensions: Length, 120 to 185 μ; distance between knees of antapicals, 70 to 130 μ; between tips, 60 to 112 μ; altitude from apex to middle of posterior margin of the midbody, 75 to 110 μ; altitude from apex to middle of posterior margin of the midbody, 75 to 110 μ; altitude of midbody to base of anterior process, 30

to 50 μ; dorso-ventral diameter of midbody, 32 to 48 μ; length of horns, 45 to 95 μ; rarely 130 μ.

Taken frequently in small numbers in vertical hauls from 135–30 fathoms to the surface, and rarely in surface catches off San Diego.

Triposolenia ramiciformis sp. nov.

Pl. 17, fig. 8.

A grotesque species of slender habitus, with midbody pendant from the base of the dorsal antapical horn, convex epitheca and capitate head, elongated neck, and elongated basally spreading antapicals, with tuberculate major flexures and pointed ends.

The midbody of this species is laterally compressed, sack-shaped in lateral view with broadly rounded antapex, usually tapering but little till near the antapex, though several specimens have been seen in which the midbody tapers gradually from the base of the antapicals to the more narrowly rounded apex. The length of the midbody along its major axis is 1.67 (1.5–2.0, rarely 2.5) times the mean dorso-ventral diameter and 1.15 (1.1–1.3, rarely 1.7) times the distance between the bases of the horns. The main axis of the midbody is oblique to that of the neck, the angle of divergence being 12°–25°.

The two antapicals emerge from the midbody, not from the posterior part as in *T. truncata* and *T. bicornis*, but from the anterior angles. The ventral horn and the anterior projection emerge together from the ventro-anterior angle and the dorsal one from the dorso-anterior angle. The ventral horn is slightly anterior to the dorsal one, so that the anterior margin is somewhat oblique to the main axis of the midbody. It usually has a small convexity nearer the base of the dorsal horn.

The two horns are subequal and subsymmetrical with respect to the midbody, the ventral is usually a little longer than the dorsal. In length the ventral horn is 2.9 (2.5–3.3), and the dorsal 2.7 (2.5–3.2) times the altitude of the midbody in its main axis. In a few cases the dorsal horn is the longer. The horns are of fairly uniform caliber throughout, the length of the ventral being 24–28 times its width. The tips are bluntly pointed.

From their origin the horns diverge latero-posteriorly, leaving the midbody almost at right angles to its major axis and curving posteriorly within 1.5 altitudes of the midbody from their origin. This major flexure is usually gradual, but may be more or less abrupt. At the level of the posterior third of the midbody the horns have a direction nearly parallel to its major axis and are then slightly incurved while the ends are again slightly outwardly curved. In the region of the major flexure and below it each horn bears on its outer surface 2–5 low tubercles.

The anterior process rises from the midbody above the base of the ventral horn in a direction nearly parallel to its ventral margin. Above the pharynx the slender, straight, or slightly curved neck is bent dorsally at an angle of about 30°. The region of the flagellar pore is quite protuberant, its dorso-ventral diameter being fully twice that of the adjacent neck. The head is capitate, its dorso-ventral diameter being 1.5–2 times the width of the head. The neck is about 0.75 of the total length of the anterior process. The epitheca is convex and the transverse furrow scarcely impressed. The transverse lists are low, spreading with many fine ribs. The longitudinal lists are salient about the flagellar pore and the left bears a prominent suture spine.

The thecal wall is hyaline, structureless. A few pores can be found in the ventral sagittal suture of the neck, and in the tubercles of the major flexures.

The nucleus is lenticular in form, laterally compressed, and lies in the posterior part of the midbody. Chromatophores, few, irregular in form, yellowish green.

Dimensions: Length, 152–160 μ; altitude of midbody in main axis, 37–43 μ; length of anterior process, 56–72 μ; length of posterior horns, 95–140 μ.

Taken sparingly in vertical hauls from 100 fathoms off San Diego.

Triposolenia exilis sp. nov.

Pl. 17, fig. 8.

This is a species of the *T. ramiciformis* type with pendant midbody. It differs from that species in having a narrower midbody, a less oblique and more curved neck and antapical horns less widely spreading.

The midbody is long and narrow, its dorso-ventral diameter taken midway of its length, being 0.4 of its axial length. Its dorsal and ventral margins are subparallel, tapering but little posteriorly. The antapex is bluntly rounded, being almost truncate. The length of the midbody equals that of the head and neck, equals the distance from its antapex dorsally to the dorsal horn, is a little more than the corresponding distance to the ventral horn and is somewhat less than 0.25 of the total length. The anterior process extending from the midbody to the flagellar pore has the usual size and proportions. The neck is nearly parallel to the general trend of the antapicals and the long axis of the midbody, being bent dorsally in a gentle curve about 12° from a parallel to the axis. The head is spheroidal with a convex epitheca.

The antapicals arise as in *T. ramiciformis*, but begin at once to curve posteriorly in an arc which brings them to an antero-posterior direction within the length of the midbody, thus nearly obliterating the localized major flexure seen in *T. ramiciformis*. The sigmoid posterior curvature of the antapicals is freely developed. The tips are rounded, without spinules. There are 2–3 feebly developed tubercles on the dorsal and ventral margins respectively of the dorsal and ventral horns within the level of the midbody. The lateral curvature in the antapicals has not as yet been determined. The length of the dorsal and ventral horns is 2.1 and 2.3 times the axial length of the midbody respectively. The inequality in the antapicals is greater than in any other species here described. The distance between the antapicals at the level of the antapex of the midbody and at the tips are respectively 1.8 and 1.6 times the axial length of the midbody.

The thecal wall is hyaline and not pitted nor reticulate. The transverse lists are faintly and sparingly ribbed and the longitudinal ones are without structural differentiation. A faint suture spine is located posterior to the flagellar pore.

Dimensions: Length, 165 μ; altitude of midbody, 45 μ; length of anterior process, 61 μ; length of antapical horns, 94 and 103 μ.

Taken in vertical haul from 100 fathoms off San Diego in July.

The following tabular comparison of characters will facilitate the separation of *T. ramiciformis* and *T. exilis*.

	Obliquity of neck	Ratio of length and dorso-ventral diameter of midbody	Distance between antapicals at level of tips	Distance between antapicals at level of midbody	Major flexure
T. exilis	12°	3.2:1	1.6 lengths of midbody	1.6 lengths of midbody	Diffused
T. ramiciformis	24°	3.1:1	2 lengths of midbody	2.5 lengths of midbody	Localized

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October 3, 1906.

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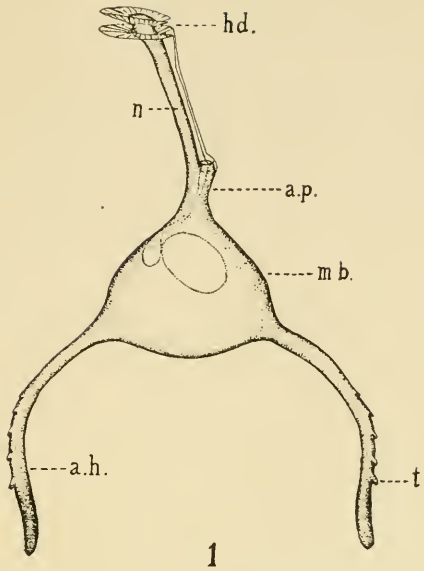
PLATE XV.

Fig. 1. Right side of *Triposolenia bicornis* sp. nov. × 514.

Fig. 2. Cell contents of *T. bicornis*, viewed from the left side. × 740.

ABBREVIATIONS.

ac.pus.—accessory pusule.
a.h.—antapical horn.
a.p.—anterior process.
can.—efferent canal.
chr.—chromatophore.
c'ph.—cytopharynx.
f.p.—flagellar pore.
hd.—head.
mb.—midbody.
m.f.—major flexure.
n.—neck.
nu.—nucleus.
pus.—pusule.
t.—tubercle.



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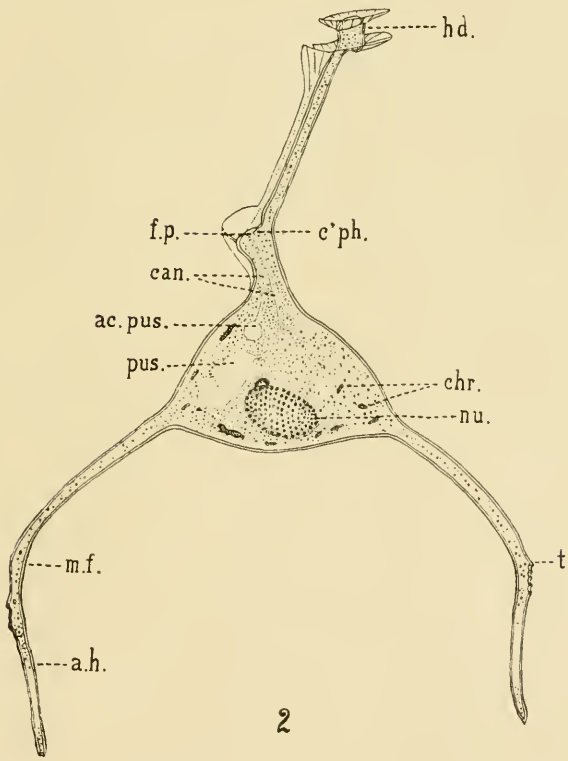

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PLATE XVI.

Fig. 3. Right side of *Triposolenia depressa* sp. nov. × 506.

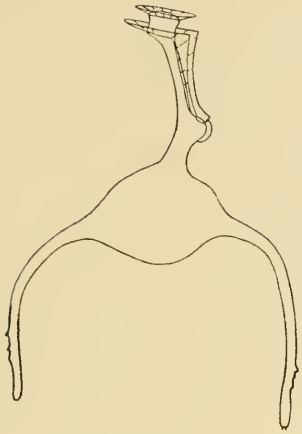
Fig. 4. Dorsal view of the same. × 506.

Fig. 5. Right side of *T. truncata* sp. nov. × 506.

Fig. 6. Anterior part of *T. bicornis*. × 1200.

ABBREVIATIONS.

a.l.—anterior list.
d.a.h.—dorsal antapical horn.
f.p.—flagellar pore.
n.—neck.
p.l.—posterior list.
tr.f.—transverse furrow.
tr.fl.—transverse flagellum.
s.sp.—suture spine.
v.a.h.—ventral antapical horn.



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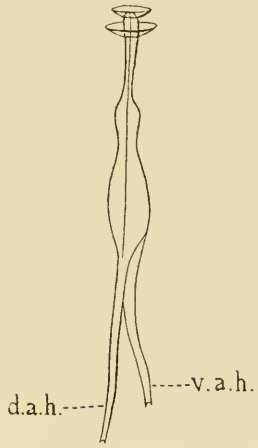

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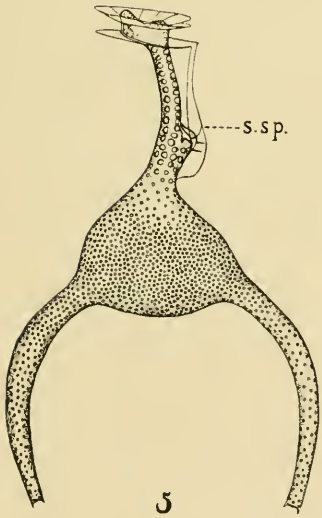

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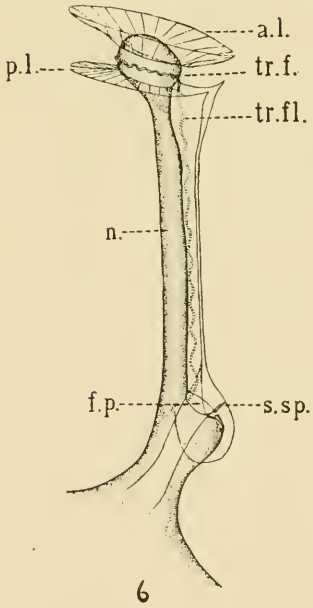

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PLATE XVII.

Fig. 7. Left face of *Triposolenia ramiciformis* sp. nov. × 487.

Fig. 8. Right face of *T. exilis* sp. nov. × 487.

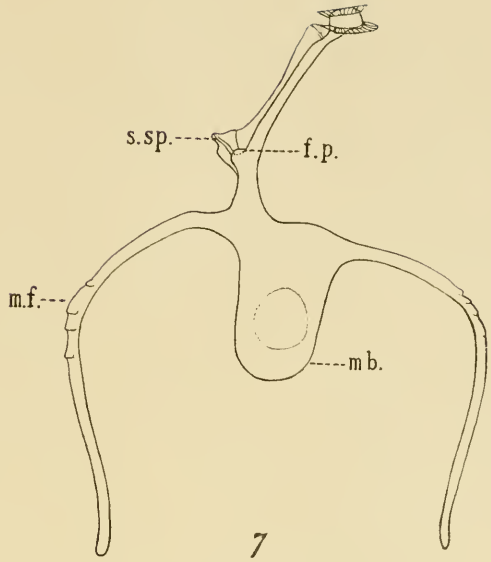
ABBREVIATIONS.

f.p.—flagellar pore.

mb.—midbody.

m.f.—major flexure.

s.sp.—suture spine.



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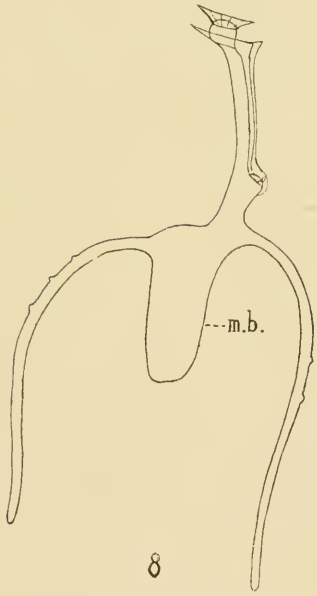

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

ZOOLOGY

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A DISCUSSION OF SPECIES CHARACTERS IN TRIPOSOLENIA.

I.—The Nature of Species Characters.

II.—The Adaptive Significance of Species Characters.

III.—The Coincident Distribution of Related Species.

BY

CHARLES ATWOOD KOFOID.

I. The Nature of Species Characters in the Genus Triposolenia.

The genus *Triposolenia* is sharply set off from other genera of the *Dinophysidae* by the pronounced form of its midbody and the relation which this bears to the balanced antapical horns and to the anterior process. As yet no species have been found which will afford a transition between *Triposolenia* and the most nearly related genus *Amphisolenia* which has a fusiform midbody and a single simple or branched antapical horn.

The characters by which the species of *Triposolenia* may be distinguished from each other are principally the form of the midbody, the origin of the antapical horns, as well as their curvature, spread and tips, the curvature and obliquity of the neck, and the shape of the head, especially of the epitheca. The structures least modified are the anterior process, the lists and collars.

Differentiations of the thecal wall appear only in *T. truncata*. Differences in position of nucleus and vacuoles and in the number, form, and color of the chromatophores and plasmosomes appear to have little significance in the matter of specific distinctions.

The *size of the organism* is also of aid in distinguishing the species. This is shown very strikingly on a comparison of drawings of numbers of individuals of the several species made to the same scale. It appears at once that *T. depressa* and *T. truncata* are small species, that *T. bicornis*, *T. ambulatrix*, and *T. exilis* belong to a series of medium sized species, and that *T. ramiciformis* and *T. longicornis* are the largest ones. Variations in the length of the antapicals and of the neck are the principal cause of fluctuations in the size. In the cases *T. bicornis*, *T. truncata*, *T. ramiciformis*, and *T. longicornis* where a number of individuals have been measured, the extreme measurements are usually relatively rare and most of the individuals lie very near the mean. There is thus a norm in the matter of size for each species.

It comes frequently to be a matter of experience to one who examines many organisms with a view to assorting them according to their kinds, that differences are detected *en mass*, without analysis of the individual differentials which together constitute the facies or *ensemble* of characters which is diagnostic of the species. In a relatively simple organism such as *Triposolenia* these individual structural characteristics of the species may be readily isolated and a comparison of their assemblages and relations affords some data bearing on the nature and origin of species.

The accompanying table of species characters of the eight known species in this genus has been drawn up to include those characters which are most easily defined or simply expressed. Others, principally in the more complex matter of proportions of various parts, might be added to the list.

It might be supposed that in so simple an organism as *Triposolenia* species might be separated by single characters. An examination of the table and the plates will suffice to show that this is decidedly not the case. For example, *T. truncata* differs from its nearest relatives, *T. bicornis* and *T. depressa* in *size, shape of head and epitheca, length, curvature, and angle of the neck, proportions of the anterior process, shape of the midbody* (from *T. depressa* only), *proportions, curvature, and spread of the antapicals as well as in their tips.* There is, indeed, scarcely an element of the organization which on close examination does

SPECIES CHARACTERS IN TRIPOSOLENIA.

		Midbody				*Antapical horns*		
Species	*Length in μ*	*Form in lateral view*	*Margins*	*Head*	*Epitheca*	*Origin*	*Major flexure*	*Tips*
truncata	128 (113-145)	subtriangular	moderately convex equal	much flattened	concave	posterior	slightly localized	truncate spinulate
depressa	100-122	subelliptical	strongly convex nearly equal	elongated capitate	convex	posterior	distributed	nearly truncate spinulate
bicornis	150 (130-176)	subtriangular	slightly convex nearly equal	flattened spheroidal	slightly convex	posterior	localized	pointed
ambulatrix	158	irregular oval	diversely convex unequal	spheroidal	convex	posterior	distributed	blunt and spinulate
fatula	175-190	triangular	concave anteriorly unequal	spheroidal	convex	posterior	distributed	spinulate
longicornis	230 (210-240)	triangular	very slightly convex equal	flattened	flat	posterior	distributed	rounded
exilis	150	elongated	sides nearly parallel	flattened capitate	slightly convex	anterior	localized	blunt
ramiciformis	159 (154-175)	nearly oval	not parallel	flattened capitate	slightly convex	anterior	localized	blunt

not exhibit a difference in the species in question. These differences are not so pronounced between *T. bicornis* and *T. depressa* as between *T. exilis* and *T. ramiciformis*, nevertheless it is evident that even these more nearly related couples are distinguished at once by a complex of characters rather than a single one or even a few. The differences between *T. exilis* and *T. ramiciformis* are discussed under the description of the former. The differences between *T. bicornis* and *T. depressa* are in size, form of midbody, proportions of neck and of cytopharyngeal region, and in the tips of the antapicals. The elementary characters of the organism are thus fundamentally and extensively different in their form and relations in the different species in this genus. It is as though they had been thoroughly shaken up and readjusted in the case of each species, when nature cast the die.

The individual species characters are all subject to variations of the fluctuating kind, in varying degrees of amplitude. Thus the length of neck and the convexity of the margins of the midbody are quite variable. Variation is least evident in the anterior process, and the head. The greatest variation is perhaps found in the antapicals, in their length, in the spread, degree, and localization of their curvature, in the number and distribution of the tubercles and in the form of their tips. *Triposolenia* is probably a divergent member of the *Dinophysidae*, and it may be that the antapical horns, especially the dorsal one, are phylogenetically recent structures. They are also peripheral in location, though no more so than the head in which fluctuating variations are less evident.

These fluctuating variations often cause an individual of one species to approach another in some one or even several characters, as, for example, *T. truncata* falls within the size limits of both *T. depressa* and *T. bicornis*, but approach in size is not accompanied by a proportionate change in the same direction in *all other differential characters*. Again the antapical tips of *T. depressa* are sometimes partially truncated, but there is no coincident fluctuation in the pitting of the thecal wall or flattening of the epitheca characteristic of *T. truncata;* in other words, variation is not total in the direction of a given species.

II. The Adaptive Significance of Specific Characters.

In view of the current discussion among biologists of the adaptive significance of diagnostic characters which separate species and of the efficiency of natural selection in the origin of these characters, individually or in their totality, it is a matter of interest to consider what light the organisms with which we are here dealing throw upon this vexed question. The relative simplicity of their organization and the fact that the specific distinctions are comparatively few, probably less than a dozen being revealed in the theca on the closest scrutiny, and further that they are expressed in the more permanent exoskeleton or thecal[1] wall where they are preserved in fixed form for comparison, and of still greater significance the fact that they have had their origin in the surface waters of the sea, a region of relative environmental uniformity and possibly the primitive home of organisms (Brooks '95), all conspire to reduce the problem to its lowest terms and to lend an unusual interest to its consideration.

The problem is here freed from the complexities which attend its consideration in the higher organisms where multiplicity of parts makes difficult the expression of the total specific differences, where the mobility and contraction of the organism or its constituent parts renders impossible a precise definition of all the diagnostic characters, and where the period of growth is long continued and the total form-cycle of the individual in which the species characters are expressed is more extended in time and of greater amplitude in its modifications. Incomplete as our conception of the ensemble of specific characters in *Triposolenia* must be, the conditions are such as to afford a nearer approach

[1] It is of course probable that all of these skeletal characters exhibited in the non-living cellulose skeleton are the expression of the many coördinated internal metabolic processes of the nucleus and cytoplasm of the cell, processes which, moreover, are of an ephemeral nature in the cyclic process which culminates in the new formation of the half-theca at the time of cell-division when the parental theca is parted in the sagittal plane and each daughter cell reproduces the lacking half of the thecal wall. Sexual reproduction is as yet unknown in this family and, indeed, has been rarely observed in the Dinoflagellates as a whole, and is as yet unrecorded among the marine species. Judging from the trend of discoveries in the life-histories of the Protozoa its occurrence is to be expected generally among the Dinoflagellates. Should it occur it is probable, from the observations of Zederbauer (:04), that complete formation of a new theca about the zygote or its offspring will be found to take place after union of the gametes.

to a comprehension of the total organism than can be attained in a more complex organism living in a more diversified environment and descended through a more diversified ancestry.

Are the diagnostic characters of the species of *Triposolenia* adaptive? Do they have a survival value to the organisms which possess them? Does the survival value attach itself to the sum total of the species characters or to but one or several, and are the remaining ones in this case to be "explained" as a result of coördination?

If the differentiation of the species in this genus is the result of a struggle for existence it necessarily follows that a survival value attaches to the *differential* characteristics, either to their sum total, which in the case of *Triposolenia* we find to include a considerable number of correlated elements, or to one or more of the individual structural characters to which all the others must then be linked in some necessary relation that is expressed by the term coördination. In assigning natural selection as the cause of the species characters in *Triposolenia* we are at once confronted by the difficulty of finding any evidence of the *differential* survival value of any of the characters in question. Presumably competition is severest between individuals of the same or closely related species and species of related genera. It is, however, impossible to establish the fact of any advantage accruing to one of these species over its nearest allies by reason of its structural distinctions and difficult to find any satisfactory basis for a logical inference or conclusion to that effect.

The structural adaptations in *Triposolenia* are evidently directed toward the development of a specific skeletal surface sufficient for the necessities of flotation, the distribution of skeletal matter with reference to orientation, and to the exposure of the protoplasmic contents to the action of light and of substances in solution in the water. It is conceivable, and indeed probable, that *all* the types of midbody, of form, proportions and curvatures of the antapicals and neck are adaptive, or at least are not unadaptive in these directions, and that the pitted surface of *T. truncata* is adaptive in compensation for its shorter horns, but the various forms of head and antapical tips and the distributions of tubercles are less clearly of utility. That *all* of these

specific types are fitted to survive is witnessed by the coincident occurrence of at least five of the species in the San Diego area, and it is not improbable that prolonged search will bring the other three to light in that region. While it is not probable that all of the species are *all equally well adapted to survive* it is evident that they have been and are *sufficiently* well adapted to maintain themselves.

It is conceivable that all variations or mutations which have weakened the coherence of the parts or increased or decreased the specific gravity or specific surface beyond certain limits would result and may have resulted in the extinction of these unfit individuals which have passed the "dead line" into the territory where selection becomes operative. It is equally probable that many types of form and proportions of the structural elements of *Triposolenia* might occur and may have occurred upon which selection is entirely inoperative by reason of the fact that they lie within the circle of permissable adaptive changes at whose circumference natural selection lies in wait. For example, it is impossible to see how natural selection can account for the triangular, elliptical and the two pendant types of midbody in *Triposolenia*. All afford approximately equal form resistance, specific surface, and exposure for metabolism. That one type is about as effective as another, or at least sufficiently effective, is evidenced by their continuance in a common environment. The same statement might be made with reference to other diagnostic structural features of the several species. In *Triposolenia* we have an illustration of the occurrence of a number of types of structure, apparently of specific rank, types defined by a number of structural elements rather than by a single one or a few, types, moreover, which are apparently not linked together by coincident variations of the fluctuating nature of all the characters involved, and these types, or species as I believe them to be, all appear to lie within the circle of permissible adaptive modifications where natural selection is inoperative. The utility of each of the complexes of characters is sufficient for their preservation without the necessity of calling in natural selection to account for their differentiation and continuance. It is not difficult to imagine a number of types of *Triposolenia,* modifications of the structural

elements which the genus presents, which may occur as additional species, and it requires no gift of prophecy to predict that continued exploration of the sea will bring to light additions to the genus.

If then natural selection does not originate the specific characters of *Triposolenia* we are forced to seek some other explanation of the complex of structures found in the organization of each species. The mutation theory of De Vries (:05) affords a conception of the origin of these species which avoids the difficulties attendant upon the absence of differential survival values of the specific characters and also lends itself readily to the view here advocated that specific distinctions involve not a few but many characters of the organism.

III. The Coincident Distribution of Related Species of Triposolenia.

The data available for the critical determination of this question are inadequate at present. In the first place the individuals are always relatively rare, 1–6 representing the number of individuals usually found in a haul of a 14-inch net. Again, closing net catches have not been examined in sufficient numbers and from sufficient localities to determine the *vertical* distribution of the species. It is possible that there may be a differential vertical distribution and that temperatures may form barriers between the species. I have no conclusive evidence on this point at present. The programme of the San Diego Station includes an investigation of the vertical distribution and movements of the plankton. It is hoped that precise evidence on this matter of temperature barriers and vertical distribution will be forthcoming. The facts are as follows: All species except *T. ambulatrix* and *T. longicornis* have been found within an area of a few square miles off San Diego in hauls within 100 fathoms of the surface. A number of hauls from 200–300 and even 400 fathoms have been made, but they do not show any increase in the number of individuals of *Triposolenia*. The hauls have been made in most cases by lowering the nets to the desired level and towing for 10–60 minutes and then bringing the open net to the surface. This affords an assumption in favor of a considerable part of

the contents coming from the deeper levels since the net does not filter on the descent and has its filtration efficiency reduced during its ascent. The individuals of the various species of *Triposolenia* have been found with a single exception only in the hauls from below the surface, and principally in those from the 70–130 fathom levels. Frequently several species have been found in a single catch. Representatives of this genus are extensively distributed throughout the Eastern warm temperate and tropical Pacific. It is not improbable that Schütts' ('95) *Amphisolenia tripos* (*nomen nudum*) from the Gulf Stream is a member of this genus. The investigations of Cleve ('01 and '02) and others have shown the cosmopolitan nature of the distribution of the pelagic Dinoflagellates. My own observations on the plankton of the Pacific confirm this view. *Triposolenia* is not a genus restricted in its distribution and the species here described are not local forms. They will be found, beyond question, widely distributed in the warmer seas. Over against the possibility of barriers of temperature separating them in their vertical distribution should be placed the probability of some vertical movement as a result of vertical currents (see Holway :05) and also as a result of heliotropism, the latter varying with the amount of carbonic or other acids in the water (Loeb :03). In any case the coincident distribution of closely related species is a common feature among the pelagic protozoa with which I am familiar, *e.g.*, among the Coccolithophorida, the Silicoflagellata, other Dinoflagellata, the Radiolaria, and the Tintinnidae. That these primitive animals should have attained so high a degree of specific differentiation in the presence of so great environmental uniformity, in the relative absence of barriers, is a fact of profound significance to be taken into account in any discussion of the process of organic evolution.

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October 3, 1906.

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ON THE SIGNIFICANCE OF THE ASYMMETRY IN TRIPOSOLENIA.

BY
CHARLES ATWOOD KOFOID.

The appearance in *Triposolenia* of an asymmetry caused by the deflection to the left of the posterior ends of the antapicals and a similar asymmetry in a number of species of *Amphisolenia* (Kofoid :06) leads to a consideration of the significance of this somewhat widespread phenomenon. Had it appeared as one of the characters of a single species, or even of several, it would be dismissed as one of those usual chance vagaries of structure which so often crop out in the diagnostic features of a species. Its occurrence in the two genera named and suggestions of an analogous structural feature in some other genera of Dinoflagellates is indicative of a more profound relationship to the welfare of the organisms in which it appears.

Locomotion in this genus, as in other Dinoflagellates, is brought about by the combined action of the two flagella. The transverse flagellum causes rotation about the antero-posterior axis of the body, or rather about the axis of the spiral of progression, while the longitudinal flagellum is the principal organ of propulsion, though it may also assist in the rotation. The combined effect of the activity of the two flagella is to cause the organism to move forward in a spiral course about a more or less straight line of progression as shown in Fig. A. The rotation may be in either direction, that is, dexiotropic or leiotropic. A more precise definition of the motion is possible by using the axes and poles of symmetry of the organism. The dexiotropic rotation

Fig. A. Diagram of locomotion in Triposolenia.

of an organism with its antero-posterior axis in a horizontal position is brought about by a turning of its body on this axis in the direction of its left over to its right, and the leiotropic by turning in the opposite direction, to wit, from its right over to its left. In the Dinoflagellates generally the rotation is predominantly from left over to right and structural differentiations which favor this predominance in the direction of rotation are not infrequent, such, for example, as the distal displacement of the girdle giving to it the form of a descending right spiral. Such differentiations usually result in some bilateral asymmetry. The only structural character of this sort in *Triposolenia* appears to be the asymmetry in the lists about the flagellar pore.

As Jennings[1] has clearly shown, this rotation upon the axis, with resulting spiral course of greater or less radius, is a most effective means of securing progression in a definite direction. The radius of the spiral is largely influenced by the degree of asymmetry of the organism, being greater as the asymmetry increases.

There is in *Triposolenia*, however, a form of bilateral asymmetry which, though it may be coördinated with the spiral rotation of the organism, is nevertheless also a most perfect adaptation to flotation in that it serves to orient the body during passive descent in response to gravity, in the position of greatest resistance. I refer to the distal deflection of the tips of the antapical horns to the left.

The principal necessity which confronts pelagic organisms is that of keeping within range of the food supply, which for most organisms means keeping within a certain distance of the surface of the sea. In the case of *Triposolenia* the organism is dependent to some extent upon illumination for its synthetic processes. The degree of light necessary is apparently not great since its center of distribution appears to be nearer the hundred fathom line than to the surface. The constant action of gravity tends to draw the organisms below the levels of optimum illumination. It is essential, then, to the welfare of the organism that its locomotor activities should preserve its location in the region of optimum

[1] Jennings, H. S.: On the Significance of Spiral Swimming of Organisms. Am. Nat., Vol. 35, pp. 369-378, 11 figs., 1901.

illumination. This could be accomplished by the mode of locomotion above described, provided that the organisms were oriented with their heads uppermost. The form of the midbody, especially in the pendant type, and of the antapicals, is strongly suggestive that they may serve as organs of orientation. If they have this function it may result either from a greater specific gravity posteriorly, or from a smaller specific surface in the same region, or it may be from both. The lists suffice to give the anterior part a greater specific surface than is found posteriorly, and in the passive sinking of the organism this difference would tend to hold the anterior end uppermost. Treatment with osmic acid reveals an accumulation in the head and neck of fatty or oily substances which turn a darker brown than the cell contents elsewhere in the body. The presence of these lighter substances here would also tend to keep the anterior end uppermost. Furthermore, it may be that these organisms exhibit a positive heliotropism for certain intensities of light, as do some other Dinoflagellates, and that this reaction would result habitually in their active orientation with the anterior end uppermost in levels of optimum illumination. The orientation of the body may thus be passive, as a result, when the organism is sinking, of the molecular friction of the water on the greater specific surface of the anterior end, or as a result of its smaller specific gravity, or it may be active, resulting from positive heliotropism. In any case, given this orientation, locomotion will result in movement toward the surface away from the ceaseless pull of gravity.

There is one disadvantage to the organism in this orientation in that its form resistance to the pull of gravity is small. Indeed the area of the water displaced by *Triposolenia* in sinking while in a vertical position is the least possible, being less than with the dorsal or ventral edge below, and very much less than it would be if the organism lay on either side. In the case of *T. depressa* the displacement area in the vertical position is about 390 square micromillimeters, with the ventral edge below it is 540 square micromillimeters, while on one of the lateral faces it is about 1,200, or nearly three times as great.

It is obvious that passive sinking as a result of the pull of gravity, if long continued, would carry the organism below the

limit of optimum illumination, or even beyond possible photosynthesis. The return to the optimum levels can only be made at some expense of energy. Any structural provision, therefore, which lowers the rate of sinking will be of distinct advantage in that it prolongs the stay at optimum levels, and reduces the expenditure of energy in the return to such levels, when once gravity gets the upper hand of the locomotor powers of the organism.

Temporary cessations in the locomotor activities of *Triposolenia* expose the organisms to the action of gravity and descent begins while the organism is in a vertical position, with the minimum form resistance to the downward movement.

It is obvious that if the organism should turn so that it should lie on the side the area of displacement would be greatly increased and the descent delayed. *This is accomplished by the terminal asymmetry of the antapical horns in Triposolenia.* As has been indicated in the description of the species in the previous paper, the ends of the antapicals are bent to the left for a short distance in all species which have been examined on this point. The effect of this asymmetry is to turn the organism upon its right face, as soon as it begins to descend while oriented with the anterior end uppermost. The greater resistance offered by the right face of the tips veers the antapices to the left and throws the organism over on its right side, as shown in Fig. B. This may be beautifully demonstrated by dropping in the air a paper model of *Triposolenia* in which the antapicals are slightly bent. The turning of the model, made from a drawing showing an enlargement of 675 diameters, is accomplished easily within a meter of descent, and often in less than that distance, that is, within ten lengths of the organism. The rapidity and despatch with which the model turns is remarkable and is significant of the effectiveness of this structure in changing the orientation of the organism when sinking with a vertical orientation.

The deflecting effect of the bent ends of the antapicals naturally decreases as the organism turns upon its side, since they include a rapidly decreasing proportion of the total surface of resistance. When once turned upon the side the horizontal orientation of the model continues for a short time and the descent proceeds with frequent changes of position in a fluttering, waver-

Fig. B. Diagram of sinking *Triposolenia.*

ing manner which involves frequent returns to the horizontal position. In the case of *Triposolenia* in suspension in the sea-water, to whose specific gravity it closely approaches, the horizontal position and the subsequent shiftings presumably occupy a longer time than in the case of the model in the air. This is easily demonstrated by sinking a model of firm hard paper in a tall jar of water.

Other genera than *Triposolenia* exhibit this type of asymmetry. It is seen in a similar structural deflection in the allied genus *Amphisolenia* in a large number of species, especially in those of linear form. Linear species of Ceratium also have marked deflection of the left antapical horn to the left and dorsally. This is noticeable in *C. fusus* Ehrbg. and *C. strictum* (Okamura). In species of *Ceratium* with anteriorly deflected antapicals the two horns are sometimes deflected ventrally in a sweeping curve. In *Peridinium* and *Heterodinium* the girdle is often oblique antero-dorsally and ventro-posteriorly. These various types of asymmetry all have the tendency to orient the passively sinking organism broadside to the direction of descent and thus to increase the area of resistance. These forms of bilateral or dorso-ventral asymmetry among the Dinoflagellates are thus adaptative to flotation.

Zoological Laboratory, University of California,
October 3, 1906.

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II. LITTORAL FORMS

BY

CHANCEY JUDAY

XV

CLADOCERA OF THE SAN DIEGO REGION

BY

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XIV.

OSTRACODA OF THE SAN DIEGO REGION.

II. LITTORAL FORMS.

BY

CHAUNCEY JUDAY.

As stated in the paper on Haloeypridae, very few of the thousand plankton catches examined were made in the shallower water, and of these only nine contained littoral forms of Ostracoda. The various forms represented in this small number of catches belong to the two groups Podocopa and Myodocopa.

PODOCOPA Sars, 1865.

Shell never with antennal sinus. The inner branch of the antenna more strongly developed than the outer; the former three- or four-jointed, the latter sometimes two-jointed, but usually without joints. Maxilla always with a respiratory appendage; furca either rudimentary, or when developed, consisting of slender, elongated laminae which bear few terminal spines.

Family CYTHERIDAE Baird, 1850.

Shell extremely variable in form, usually strongly calcareous and firm; often with a complex sculpture. Antennule with five to seven joints, second and third always fused. Antenna without natatory setae; fourth joint of inner branch usually with three claws or setae. Mandible three- or four-jointed; exopodite usually developed as a respiratory plate. Three pairs of walking

FEB 5 1909

legs. In the male a peculiar brush-like organ is found between or in front of the first pair of legs; this organ is never present in the female. Furca always small and weak, usually with two setae.

Genus **Xestoleberis** Sars, 1865.

Shell smooth, left valve somewhat larger than right so that its anterior, ventral, and posterior margins overlap the right valve when closed; a tooth at the anterior end of the hinge and one at the posterior end.

Antennule six-jointed, only moderately elongated; armed with regular setae. Antenna four-jointed (3 and 4 fused); last joint armed with two strong claws. Basal joint of mandible short; mandibular palp short, three-jointed (1 and 2 fused); with a distinct respiratory plate which bears two respiratory setae The respiratory plate of the maxilla bears a long aberrant seta which is not plumose. The three pairs of legs moderately elongated; anterior and posterior margins of the first joint of the legs with at least one seta in addition to the claw-like setae at the distal ends of these joints. In the female the furca always bears two setae, of which the upper is the longer than the lower; in the male the furca is more or less closely united with the penis, and sometimes bears three setae. The penis is always distinctly separated into a basal portion and a movable head portion.

Xestoleberis dispar Müller.

Pl. 18, figs. 1, 2.

1894. *Xestoleberis dispar*, Müller, G. W., p. 334, pl. XXV, figs. 2, 3, 9, 35.

Height of shell of female more than half the length, about 1:1.7; highest just behind the middle; dorsal margin broadly and regularly arched; posterior margin boldly arched, the boldest portion of the arch lying just above the middle; ventral margin curving in somewhat anteriorly, making a rather bold arch at the antero-ventral corner; anterior margin regularly curved. Width about equal to greatest height, sometimes a little greater than height.

Shell of male in side view nearly oval in outline; scarcely twice as long as high; dorsal margin regularly arched, ventral

not so strongly arched; anterior and posterior margins curving over regularly into dorsal and ventral. Shell of most males and females transparent; some with a brown color in the region of the attachment of the valve muscles, others with almost the entire shell tinged with brown.

Length of female 0.57; male 0.5 mm.

Catch 531, San Pedro, June 20, 1901.

Genus **Paracytheroma** nov. gen.

Shell in both male and female smooth, transparent, very thin and weak; with a small clasping process at the anterior and posterior ends of hinge. Antennule short and strong, six-jointed; the last four joints sometimes bent upward forming a knee with the second joint; the third, fourth, and fifth joints bear claw-like setae; sixth joint long and slender, about five times as long as wide; bearing three setae, one of which is claw-like, one elongated and whip-like, while the third is a club-shaped sensory seta. Antenna rather short and strong, four-jointed; last joint with two long claws. Masticating portion of mandible large and strong, armed with a number of teeth; mandibular palp four-jointed, the respiratory plate of the first joint bears two long setae. Maxilla of typical structure, with a long aberrant seta. First leg rather short, third much elongated; the first joint of the first and second legs with two setae near the middle of the anterior margin and one on the posterior margin; on the first leg this joint has two claws at the distal end, and on the second leg only one; first joint of third leg with a minute spinule near the middle of the anterior margin, a seta on the posterior margin, and a single claw at the distal end.

In the female the furca is represented by two small lobes, one arising on either side of the posterior portion of the body a short distance in front of the posterior margin; between the lobes are two bifurcated setae which arise from the body wall near the bases of the lobes. In the male the furcal-lobes are small, and are closely united to the penis; three small setae arise at the lower margin of the lobes. The penis is distinctly separated into a large basal portion and a triangular head portion.

Paracytheroma pedrensis nov. sp.

Pl. 18, figs. 3-12.

Shell of both male and female, in side view, nearly oval in outline, highest toward the posterior end; nearly twice as long as greatest height; shell thin, delicate, transparent; the ventral margin curves in somewhat in its anterior half; the dorsal margin regularly curved, the arch being boldest posteriorly; anterior and posterior margins regularly arched, passing over gradually into the dorsal and ventral margins, posterior arch bolder than anterior; seen from above, bluntly wedge-shaped, widest posteriorly; strongly compressed, greatest width equal to about two-thirds the greatest height. The inner line of the shell originates near the anterior end of the hinge, curves forward and downward forming a broad, blunt arch; the ventral portion of the line runs almost parallel to the external margin of the shell; posteriorly it forms another regular arch which is not so blunt as the anterior one; dorsally the line ends near the posterior end of the hinge.

Length of both male and female 0.57; greatest height 0.3 mm.

Several individuals were found in a plankton catch which was made in the vicinity of San Pedro, California, on July 20, 1901.

Myodocopa Sars, 1865.

Shell usually with an antennal sinus. Basal joint of antenna large, pyriform, bearing two branches; primary branch natatory, with one, rarely three elongated joints, beyond which are at least six short joints which bear setae; secondary branch small, usually larger in male than in female and formed for grasping. Mandibular palp and first maxilla without branchial appendage. Furca broad, flattened, bearing at least three strong claws or spines.

Family CYPRIDINIDAE Baird, 1850.

Shell calcareous, strong, usually with a distinct rostrum and antennal sinus. Antennule with five to eight joints; fifth joint always with a sensory organ in the male, frequently in female. Principal branch of antenna usually nine-jointed; secondary

branch usually developed as a grasping organ in the male, sometimes rudimentary in both sexes. Mandibular palp usually four-jointed and very strong, last joint bearing claws. The seventh pair of appendages originates high up on the sides of the body; these limbs are long, many jointed, and worm-like. Furca always strong and armed with several spines.

Genus **Philomedes** Lilljeborg, 1853.

Mature female.—Shell always with a distinct rostral sinus overhung by a broad, blunt rostral process; postero-ventral angle often produced into a more or less distinct projection. Eyes small or wanting. Frontal organ long and slender. Antennule six-jointed, with rather long, sparsely plumose setae; no sensory seta. Antenna with a small secondary branch. Basal joint of mandible with a masticating process which is cleft at the apex; first joint of palp with some masticating spines at the base. First maxilla rather large and strong; second maxilla with two rather large teeth at the anterior corner, the inner tooth being smaller than the outer and bifid. First pair of legs more or less distinctly jointed; outer extremity separated into lobes.

Mature male.—Shell more elongated. The fifth (fourth) joint of the antennule with a sensory seta which bears a number of long sensory filaments; last joint with two very long setae which are usually reflexed upon the limb. Secondary branch of antenna three-jointed, prehensile, the last joint reflexed upon the second. Mandible without masticating processes. First maxilla only indistinctly joined, small, weak, armed with delicate setae. Second maxilla without teeth. Eyes well developed.

Philomedes longiseta nov. sp.

Pl. 18, figs. 13-15.

The shell of the male, in side view, is oval in outline, all the corners being rather evenly and regularly rounded; dorsal margin broadly and regularly arched, ventral moderately arched; posterior margin curving off gradually into both dorsal and ventral margins, forming a bolder regular arch. The rostral process

is short, broad, and truncated anteriorly; rostral sinus shallow, widely open forwards and downwards. The surface of the valves is everywhere pitted with round, oval, or quadrangular foveolae which vary somewhat in size; marginal hairs located chiefly along anterior and posterior margins. Transparent margin of shell rather broad and thickly fringed with cilia.

The first joint of the antennule bears no setae; second joint longer than first, about as long as the rest of the limb, bearing three setae toward the distal end which are plumose in the middle; this joint also has some very minute marginal spines; third joint sub-triangular, with two naked setae on the inner margin and one on the outer; fourth with two distal setae on the inner margin and four on the outer, two of the latter setae being naked and the other four more or less plumose in the middle; the fourth joint also possesses a rather large sensory seta on its outer margin which bears a tuft of hair-like processes on its basal fourth and divides into four small branches at its outer extremity; fifth joint with only a naked seta on its inner margin; sixth with two very long setae which are reflexed upon the limb and which bear a few hair-like processes; in addition, the sixth bears five much shorter setae, two of which are rather stout, possess some hair-like processes in the middle, and branch at the outer end; the other three are slender, unarmed, and not branched at the extremity.

The second joint of the swimming branch of the antenna bears a long naked seta at its distal end which reaches as far as the sixth or seventh joint; third joint longer than second and bearing a plumose swimming seta at its distal end; the remaining joints are short and bear ten plumose swimming setae. The first joint of the secondary branch of the antenna is a little longer than wide and bears a cluster of five small setae on its proximal end, just beyond these is a longer seta which is plumose in the middle; second joint long and slender, with two, sometimes three, annulated setae; third joint about three-fourths as long as the second and reflexed upon it; this joint consists of a rather large cone-shaped base and a slenderer, curved portion; the outer end has a few crenulations and bears two, sometimes three, small setae; the basal portion of the third joint bears a very long, peculiar seta; the proximal half of this seta is large and has thin walls similar

to those of the joints; this tapers down to a small annulated portion.

The mandible is without a masticating process. The vermiform limb bears very few setae, usually four terminal and four lateral. The caudal lamina has eleven claws, four of which are long and more or less pectinate at the base; the two terminal claws are longest and strongest, above them is a small claw, then a long one, followed by another short one which is, in turn, followed by another long one; the five upper ones are small.

Length 1.9; height 1.0 mm.

Catch 124, 6 miles off whistling buoy, San Diego, June 24, 1904, surface.

Catch 221, 6 miles off Point Loma, July 23, 1904, surface tow at night.

Philomedes lomae nov. sp.

Pl. 19, figs. 1-6.

Male.—Shell rather strongly calcareous and firm; greatest height a little behind the middle; dorsal margin more strongly arched than the ventral; at the postero-dorsal angle a blunt process arises a short distance in front of the margin of each valve and extends backward beyond the margin, thus forming a projection at this angle; a large blunt projection at the postero-ventral angle; rostral process broad and blunt; antennal sinus distinct but broad and shallow; sinus narrower and more pronounced in young specimens; a small rib-like ridge posteriorly a short distance above the ventral margin and another just below the dorsal margin. Shell densely pitted with small foveolae; transparent margin of moderate width and densely ciliated.

Third joint of antennule sub-triangular, closely jointed to the fourth; the outer extremity of the fourth bears a sensory appendage which has a tuft of cilia a short distance beyond the base; the two elongated setae borne by the last joint are about one and a half times as long as the entire limb. Frontal organ long and slender, two-jointed; first joint enlarged at the base, second forming a long, slender capitulum.

Antenna.—First joint of swimming branch elongated, cylindrical; second short, bearing a medium sized, non-plumose seta

at its outer end; third joint about as long as first, armed with a plumose seta at its outer extremity; the following six joints small, and quadrangular, each with a large plumose seta, except the last which also bears a small plumose seta in addition to the large one. The secondary branch consists of three joints; first joint rather short, quadrangular, with four small setae at the base and one near the middle; second and third joints elongated, slender, forming a grasping organ; the second bears two setae near the middle; third reflexed upon second, with one seta near its base and two near its outer extremity.

Basal joint of mandible without biting process and setae; first joint of palp with three setae on the upper margin and four on the lower; on the inner side at the distal end, this joint bears a sensory appendage which is ciliated at its outer end; second joint of palp short, with two setae on its lower margin; third elongated, cylindrical, with three setae on the upper margin and a tuft of four short and two longer setae at the distal end of the lower margin; last joint small, bearing a stout claw and three setae; none of the mandibular setae plumose.

Vermiform limb with four terminal and four lateral setae. The caudal lamina bears six claws, the upper two of which are very small; terminal claw strongly pectinated; remaining claws with very minute pectinations; each claw with a few cilia at the base.

Length 1.3; height 0.8 mm.

Female unknown.

Catches 124, 571, 589, 612. For these localities see *P. longiseta*, *Cylindroleberis mariae* and *Rutiderma rostrata*.

Genus **Cylindroleberis** Brady, 1868.

(*Asterope* Philippi.)

Shell more or less oblong or elliptical, smooth; in male rather larger than in female; always with a distinct rostral sinus. Eyes well developed in both sexes. Frontal organ long and slender. Antennule six- or seven-jointed; dorsal margin with numerous plumose setae; in both sexes the fifth joint bears a sensory organ; in the female the last joint bears only rather short setae, while in the male two are unusually long, about as long as the entire

animal. Natatory branch of the antenna well developed; secondary branch small in the female, sometimes jointed, sometimes not; in male three-jointed, the third joint reflexed upon the second forming a grasping organ. Mandible strongly built; basal joint with a large, falcate, reflexed masticating process which is serrated on the edge at the tip; second joint with a backward directed lobe at the base which is armed with a few peculiar spines. First maxilla without masticating process, in its stead a group of long plumose setae; main portion of limb falcate, with many long, stiff setae on the inner margin; in front a naked lamella arises from the main limb. The second maxilla consists of a tongue-like plate which is setose on its inner margin, and a large semicircular lamina which bears many long plumose setae on its margin. The first pair of legs arises directly behind the mouth; not jointed and without lobes; bearing some plumose setae on the ventral margin. The vermiform limb has a double row of teeth at its extremity. Furca broader than long, bearing several claws. There are seven pairs of rather large dorsal branchiae.

Cylindroleberis mariae Baird.

Pl. 19, figs. 7-11.

1850. *Cypridina mariae*, Baird, p. 257, pl. XVII, figs. 5-7.
1887. *Asterope oblonga* Sars, p. 31, pl. 1, figs. 5-8; pl. II, figs. 1, 2; pls. V and VI.
1894. *Cylindroleberis oblonga* Müller, G. W., p. 219, pl. IV, figs. 14-18, 39, 41, 49-55; pl. V, figs. 1, 4, 5, 13, 14, 33, 41-44; pl. VIII, fig. 4.
1896. *Asterope mariae* Brady and Norman, p. 630, pl. L ,figs. 1-6; pl. LI, figs. 11-22; pl. LII, figs. 10-15.

Male.—Shell higher in front than behind; dorsal margin more or less arcuate throughout its entire extent; middle portion of ventral margin straight; posterior margin more or less truncate, curving over gradually into dorsal and ventral margins; rostrum large and distinct; a rather large antennal sinus situated a little below the middle of the anterior margin, directed downward and forward.

Frontal organ moderately long, bent upward at the base, and slightly dilated in the middle. Antennule six-jointed; fourth joint with a sensory organ at the distal end of the lower margin;

the sensory organ consists of a stout annulated base which bears numerous fine thread-like processes; the sixth joint bears three short and two very long setae. Antenna with the second joint of the natatory branch about as long as three of the following joints; secondary branch of antenna three-jointed, rather large and strong; first joint uniform in width, about four times as long as wide; second about as long as first, dilated on the side against which the last joint impinges, and bearing three setae just beyond the middle; third joint falcate, slender, about three-fourths as long as second, and reflexed upon it, forming a grasping organ; with a few serrations on its inner margin at the extremity and a seta near the proximal end.

The first maxilla consists of a lobe-like body portion and two acuminate arms; the smaller arm is straight and bears no setae; the outer portion of the other arm is bent around toward the body, forming a bow; the outer margin of the bow bears only two small setae and there are two at the extremity of the arm; the inner margin, except a small portion at the extremity, is densely fringed with long, slender setae. The vermiform limb bears six setae at its extremity and six on the sides. The furca bears ten claws; the upper five small, the lower five increasing in length and pectinated as well as ciliated.

Length 1.4; height 0.75 mm.

Female.—Shell in side view nearly oblong, dorsal and ventral margins scarcely arched in the middle, nearly straight; these margins curve over gradually into the anterior and the posterior. Antennal sinus narrow and deep, situated below middle of anterior margin. In both sexes the valves are strongly calcareous, smooth, and bear a few cilia along the anterior margin.

The sensory organ of the fourth joint of the antennule consists of an annulated basal portion which flattens out and divides into six thong-like processes; the sixth joint bears five setae which are about equal in length. Second joint of natatory branch of antenna scarcely as long as the two following joints; secondary branch of antenna three-jointed, the last joint being indistinctly separated from the second; the last joint bears a rather long seta. The arm-like projection of the second maxilla is twisted half way round in the female, but not twisted in the male.

Length 1.45; height 0.8 mm.

Distribution.—Adriatic (Grube); Spezzia, Messina, Goletta, Syracuse, coast of Norway (Sars); Bay of Biscay (Marquis de Folin); coast of England and Ireland, and Sicily Islands (Brady, Norman, and Robertson); Gulf of Naples (G. W. Müller); coast of southern California, catch 571, Ballast Pt., San Diego Bay, July 26, 1901, surface; catch 589, San Pedro, August 1, 1902; catch 644, San Diego Bay, July 7, 1903.

Genus **Pleoschisma** Brady, 1890.

Shell dense, surface smooth, pitted, or tuberculated; antennal sinus more or less distinct. Eyes rather small. Antennules in both sexes similar to those of *Philomedes*. In the male the secondary branch of the antenna is three-jointed, the third reflexed upon the second forming a grasping organ; in the female this branch is simple, one-jointed. Mandible with four or five joints; in the female the first joint bears a bifid masticating process, male without masticating process. The first maxilla consists of a two-jointed principal lobe and four smaller lobes, all bear setae; attached to the lobes is a large respiratory plate bearing plumose setae on its margin. Vermiform limb with a single claw-like process at its apex. Furca short and broad; armed with both setae and claws.

Pleoschisma oblonga nov. sp.

Pl. 19, fig. 12; pl. 20, figs. 1-7.

Shell of male in side view, oblong-ovate, truncate behind; about one and a half times as long as high; ventral margin broadly arched, passing over gradually into the anterior and posterior margins; dorsal margin rather strongly arched anteriorly but rounding off regularly into the posterior margin; rostrum broad, antennal sinus distinct but shallow and wide; a few short setae along margins of valves; transparent margin rather wide and densely ciliated. The surface of the shell is reticulated; these reticulations vary in size and shape, anteriorly they are arranged in rows and present the appearance of overlapping scales; in some instances, the individual areas composing the rows are not dis-

tinctly separated by cross lines; posteriorly the areas are distinctly circumscribed and are not arranged in rows.

The antennule of the male is very similar in size and armature to that of Philomedes; a sensory seta is borne by the antepenultimate joint; the basal third of this seta is enlarged and bears long, setiferous processes only on the outer side. The frontal organ is small, two-jointed; second joint enlarged, forming a capitulum. The first and third joints of the natatory branch of the antenna are elongated and together they compose about two-thirds of the length of the limb; the first joint bears no setae; second joint with a seta which is armed with short, stout spinules on its outer margin; each of the following six joints bears a long, plumose seta; the last joint bears six setae, two of which are small, the smallest possessing no plumules. The secondary branch of the antenna is prehensile, composed of three joints; first joint sub-quadrangular, with five small simple setae at the proximal end and a long seta, bearing a few plumules in the middle, at the outer end; second long and slender, with two setae on the inner margin; third nearly as long as the second and reflexed upon it, with two minute setae near the outer extremity; distal end with a few crenulations.

The basal joint of the mandible is without masticating process and setae; the first joint of the mandibular palp bears seven small simple setae and two larger plumose ones on the lower margin, and three simple ones on the upper margin; at the distal end of the upper margin is a process which bears two setae; second joint of palp much smaller than first, with four setae on the lower margin, one of which is plumose; third elongated, cylindrical, bearing seven setae on the upper margin and five on the lower; the three distal setae on the lower margin differ from the others, two of them possess a comb of minute spines on one side and have three prongs at the end, while the smallest bears some minute prongs near the end; last joint small, with three claws and three setae.

The first maxilla consists of a long two-jointed principal lobe which has a number of setae at its end, and four small lobes which also bear numerous setae; none of the setae denticulated, but some are rather stiff and claw-like, and a few are plumose.

Second and third maxillae very similar to those of Philomedes. Vermiform limb with one lateral and four terminal setae. The furca is short and sub-triangular; the marginal appendages consist of stout, spinous, pectinated claws and weak, seta-like structures; the upper two are small claws, the next three are setae, following these is a stout claw, then two more setae, another stout claw, and lastly, the large terminal claw.

Length 1.2; height 0.75 mm.

Female unknown.

Two males, catch 571, Ballast Pt., San Diego Bay, July 26, 1901; two males, catch 589, San Pedro, August 1, 1902.

Family RUTIDERMATIDAE Brady & Norman, 1896.

Antennule of female without sensory organ; antenna without secondary branch. Mandibular palp with last joint very large, terminating in a strongly developed chela.

Genus **Rutiderma** Brady & Norman, 1896.

Shell oval, truncate behind; antennal sinus variously developed, sometimes a mere notch, with no overhanging rostral process, sometimes rather large, and deep, with a distinct rostrum. Outer tooth of second maxilla three-lobed, lobes plain-edged. Furca with few ungues.

Rutiderma rostrata nov. sp.

Pl. 20, figs. 8-13.

Shell of female in side view nearly oval, rather distinctly truncated behind and somewhat higher than in front; ventral margin evenly arched; dorsal margin more boldly arched posteriorly; posterior margin slightly protuberant near the postero-ventral angle; rostrum distinct, with an overhanging beak; antennal sinus rather large and deep, opening downwards. The margins of the valves bear cilia which are longest anteriorly. A narrow, transparent marginal membrane extends from the postero-ventral protuberance forward along the ventral margin, thence along the anterior and dorsal margins to the anterior edge of the hinge; this marginal membrane is fringed with minute

cilia. The valves are densely pitted with foveolae which vary somewhat in size and shape. There are no riblets.

The frontal organ consists of a short basal portion and a long outer portion which is slender, with the exception of an enlargement near the middle. The antennule is five-jointed; first joint longest, second about two-thirds as long; third and fourth subequal in length, about two-thirds as long as second; fifth very small. The second joint bears one large and two small setae on its upper margin; third with two setae on the upper, and one on the lower margin at the proximal end, and one on the upper and two much longer ones on the lower margin at the distal end; the longer of the two latter setae bears plumules in the middle; at its outer extremity the fourth joint bears two small setae on the upper and a large one on the lower margin; fifth joint with five large setae about equal in length, and one small seta.

The basal joint of the antenna is pyriform in outline, somewhat longer than broad; swimming branch of the antenna nine-jointed, the first is long and slender; the second to eighth joints each bearing a seta, the ninth bearing five setae; setae of second to sixth joints naked, the others are plumose, with the exception of the last one on the ninth joint, which is minute and naked.

The mandible has a bifid masticating process. The mandibular palp consists of two joints and a chela; at its proximal end the first joint bears two serrated masticating spines and two setae on the lower margin; near its middle this joint also bears two short and a long seta on the lower and two large setae on the upper margin; second joint large and strong, its outer margin boldly arched and bearing three setae near the middle; outer margin with one seta at the distal end. The distal end of the second joint bears a strong chela; the outer branch of the chela is shorter than the inner, falcate, smooth-edged, with two long and two short spine-like processes at its inner end; the basal portion of the inner branch is straight, bent abruptly just beyond the middle, forming a hook-shaped apex which closes over the outer branch; its inner margin is flattened out to a knife-like, serrated edge; this edge bears a small tooth-like process at its proximal end; at the base of the inner branch, the second joint bears a small button-like nodule which possesses a minute spine.

The vermiform limb is armed with five spines at the end and four on the side.

The caudal laminae are short; each bears six ungues, the two uppermost of which are small and spine-like and are surrounded by cilia-like processes longer than themselves; the last four ungues are strong, gradually increase in length, and are ciliated on the edge; the last one bears a few teeth on its proximal half.

Length 1.2; greatest height 0.9 mm.

The male is unknown. Only one female was found.

Catch 612, Glorietta Bight, San Diego Bay, June 30, 1903.

NOTE ON THE HALOCYPRIDAE.

The paper on the Halocypridae of the San Diego Region was printed on April 9, 1906, but its general distribution was delayed till May 3. The paper of Professor Dr. G. W. Müller on the "Valdivia" Ostracoda was issued on April 25, 1906, and must, therefore, be given priority. This delay in distribution makes the following changes in the synonymy of my paper necessary.

Conchoecia giesbrechti G. W. Müller.

1891. *Conchoecia oblonga* G. W. Müller, p. 272, pl. XXVIII, figs. 26, 31, 32, 36, 37 (nom. praeoccup.).

1906*a*. *Conchoecia giesbrechti* G. W. Müller, p. 75, pl. XV, figs. 1-16.

1906. *Conchoecia pacifica* Juday, p. 21, pl. IV, figs. 5-7; pl. V, figs. 1, 2.

Conchoecia striola G. W. Müller.

1891. *Conchoecia striata* G. W. Müller, p. 270, pl. XXVIII, figs. 12-18 (nom. praeoccup.).

1906*a*. *Conchoecia striola* G. W. Müller, p. 91, pl. XVIII, figs. 11, 20-24.

1906. *Conchoecia mülleri* Juday, p. 24, pl. V, figs. 5-7; pl. VI, figs. 1-5.

Conchoecia ametra G. W. Müller.

1906*a*. *Conchoecia ametra* G. W. Müller, p. 117, pl. XXVII, figs. 11, 12, 14, 17-19.

1906. *Conchoecia ritteri* Juday, p. 25, pl. VI, figs. 6-8; pl. VII, figs. 1, 2.

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EXPLANATION OF PLATES

PLATE XVIII.

Figs. 1, 2. *Xestoleberis dispar.*

1. Shell of female. × 105.
2. Shell of male. × 105.

Figs. 3-12. *Paracytheroma pedrensis.*

3. Shell of male. × 105.
4. Portion of anterior edge of shell. × 255.
5. Antennule. × 255.
6. Mandible. × 135.
7. Maxilla of male. × 52.
8. Leg of first pair. × 200.
9. Leg of second pair. × 200.
10. First joint of leg of third pair. × 200.
11. Postabdomen of female. × 150.
12. Postabdomen and penis of male. × 160.

Figs. 13-15. *Philomedes longiseta,* male.

13. Shell. × 37.
14. Secondary branch of antenna. × 120.
15. Furca. × 60.

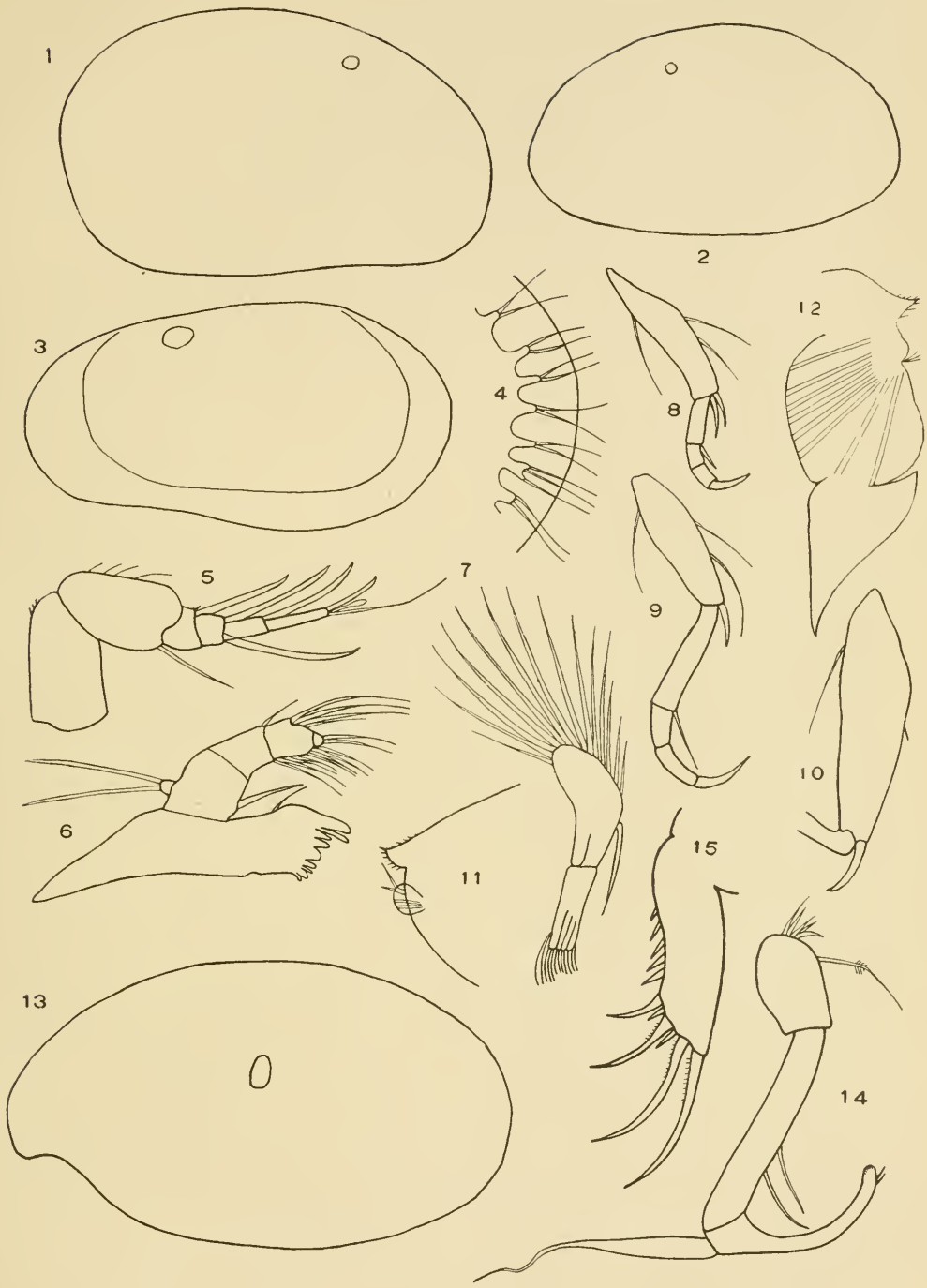
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PLATE XIX.

Figs. 1-6. *Philomedes lomae*, male.

1. Shell of adult. × 52.
2. Frontal organ. × 190.
3. Shell of young. × 52.
4. Mandible. × 105.
5. Portion of mandibular palp, showing sensory appendage. × 270.
6. Furca. × 105.

Figs. 7-11. *Cylindroleberis mariae.*

7. Shell of female. × 52.
8. Shell of male. × 52.
9. Frontal organ of male. × 275.
10. Secondary branch of female antenna. × 275.
11. Secondary branch of male antenna. × 193.

Fig. 12. *Pleoschisma oblonga*, shell of male. × 57.

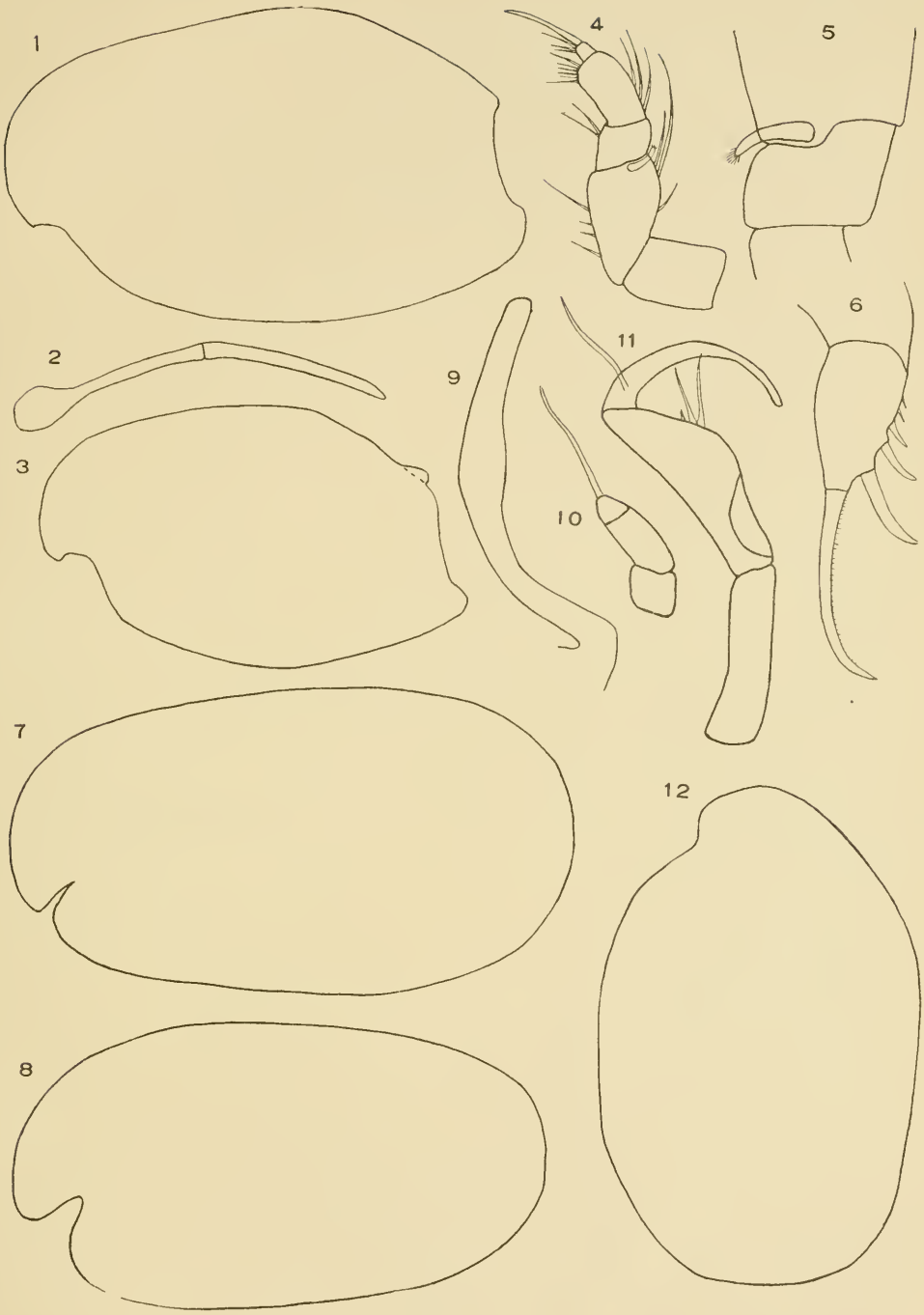
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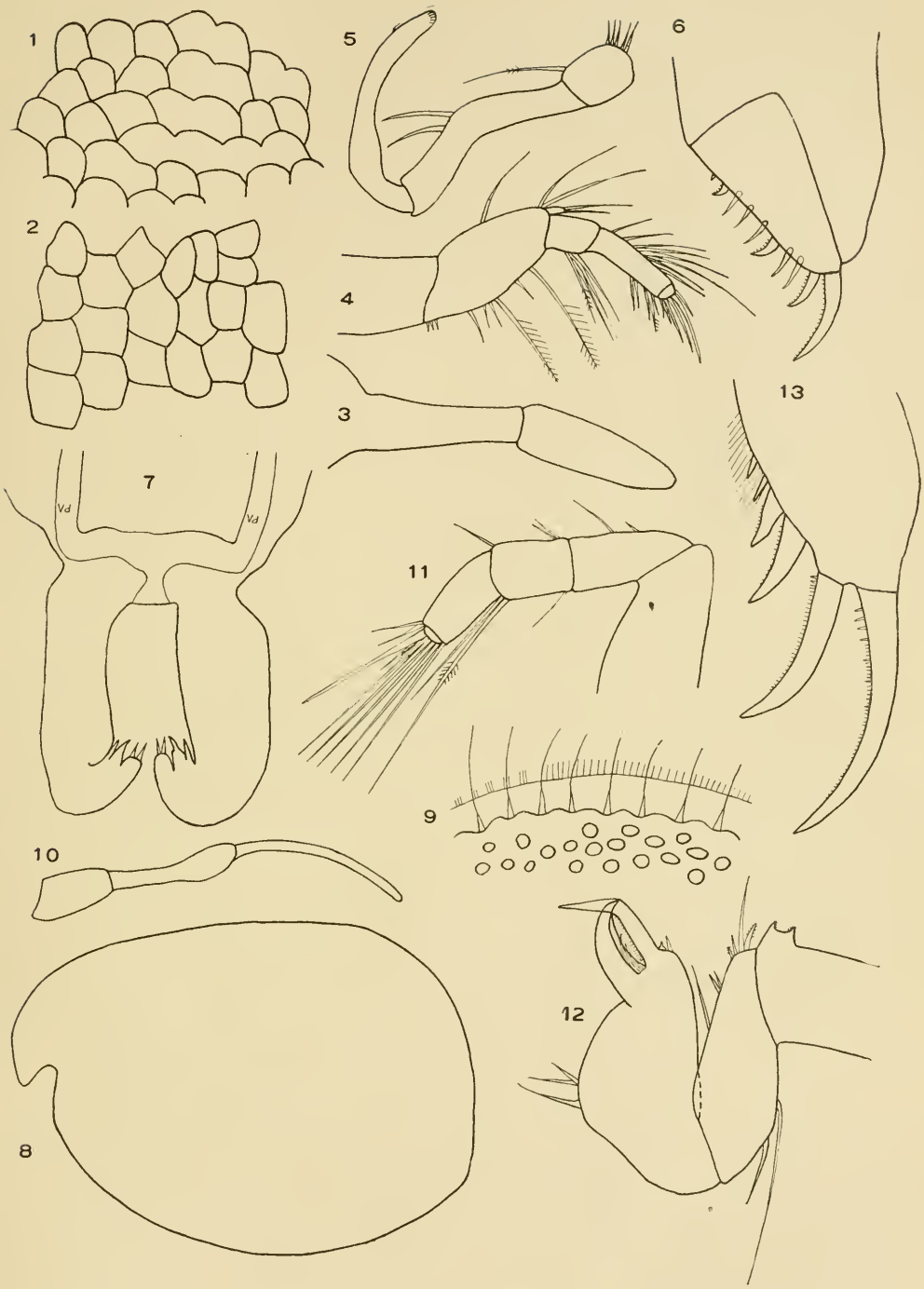
PLATE XX.

Figs. 1-7. *Pleoschisma oblonga*, male.

1. Shell markings anteriorly. × 270.
2. Shell markings posteriorly. × 270.
3. Frontal organ. 270.
4. Mandible. 105.
5. Secondary branch of antenna. × 185.
6. Furca. 105.
7. Penis. *Vd.* Vasa deferentia. × 170.

Figs. 8-13. *Rutiderma rostrata*, female.

8. Shell in side view. × 52.
9. Edge of shell antero-dorsally, showing transparent marginal membrane. × 155.
10. Frontal organ. × 155.
11. Antennule. × 110.
12. Mandible. × 150.
13. Furca. × 150.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ZOOLOGY
Vol. 3, No. 10, pp. 157-158, text figure 1 January 29, 1907

CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

XV.

CLADOCERA OF THE SAN DIEGO REGION.

BY
CHAUNCEY JUDAY.

Only one species of Cladocera was found in the thousand plankton catches that were examined.

Evadne tergestina Claus.

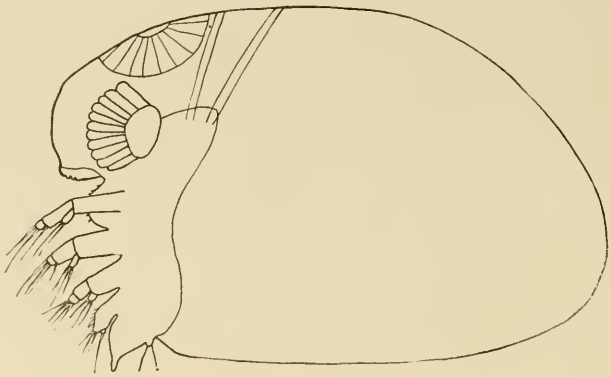
1877. *Evadne tergestina* Claus. Zur Kenntniss des Baues und der Organisation der Polyphemiden. Denkschr. K. Akadem. Wissensch. Math.-Naturw. Klasse, XXXVII, pp. 137-160, pl. 1-7. Wien, 1877.

1899. *Evadne tergestina* Hansen. Die Cladoceren und Cirripedien der Plankton-Expedition. Plankton-Expedition der Humboldt-Stiftung, II, G., d., 58 pp. 4 pl.

Shell elongated, rather broadly rounded behind, hyaline. Antennae and swimming feet relatively small; setae of antennae plumose. Outer ramus of first foot with two setae; those of second and third with three; that of the fourth foot with one seta. Elevators of antennae more or less widely separated and diverging dorsally. Neck-gland present.

Length 0.68; height 1.0 mm.

This Cladoceran was found in only eleven catches, eight of which were surface.



Evadne tergestina.

Evadne tergestina is very widely distributed. It has been found in the following localities: Florida Stream, Sargasso Sea, North Equatorial Stream, Gulf of Guinea, South Atlantic, two stations in the Indian Ocean, West Coast of New Holland, near Auckland, in Jervis Bay near Sydney, Mediterranean Sea, along the coast of southern California.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
ZOOLOGY
Vol. 3, No. 11, pp. 159-251, Pl. 21 March 27, 1907

CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO

XVI

THE MARINE FISHES OF SOUTHERN CALIFORNIA

BY
EDWIN CHAPIN STARKS
AND
EARL LEONARD MORRIS

BERKELEY
THE UNIVERSITY PRESS

Smithsonian Institution
MAY 2 1907
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ZOOLOGY

Vol. 3, No. 11, pp. 159-251, Pl. 21 March 27, 1907

CONTRIBUTIONS FROM THE LABORATORY
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MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

XIV.

THE MARINE FISHES OF SOUTHERN CALIFORNIA.*

BY

EDWIN CHAPIN STARKS
AND
EARL LEONARD MORRIS.

This paper is based upon the following material: Collections made by the senior author at San Diego during the months from December 20, 1902, to March 15, 1903, and from May 20 to August 15, 1903; by both authors at San Diego and La Jolla during the month from May 18 to June 18, 1905; a small collection made by the junior author during the last week of June, 1905, at Laguna and Newport Bay; and material collected at moderate depths by members of the Marine Biological Association of San Diego during their dredging operations about San Pedro in the summer months of 1901 and 1902, about San Diego during the same months of 1903, 1904, and 1905, including a few fishes collected about San Clemente Island in 1905.

We have endeavored to list all of the fishes that have been recorded on the California coast south of Point Conception within the fifty-fathom line.[1]

* [This paper was originally illustrated by numerous figures. The original drawings, blocks, and first proofs were destroyed in the great fire in San Francisco, April 18, 1906.]

[1] In the genus *Sebastodes* the 50-fathom line has been disregarded, and all of the species known from this region have been listed.

At San Diego Bay headquarters were established at Roseville, and the greater part of the collecting was done within a radius of three or four miles of that point, though nearly all parts of the bay were reached. Collections were made with the aid of fine-meshed seins, fyke nets, and set-lines. A few trips were made with fishermen hand-line fishing to the deep waters outside of the bay, and frequent visits were made to the tide pools on the ocean side of Point Loma, principally to the pools near the outer lighthouse. Owing to our distance from San Diego, it was not found practicable to do much market collecting.

To make the records of distribution of species more dependable, a reference is given to some authority for each record, except when the authors are themselves responsible. In the latter case the species has either been taken at the locality noted or is in the collection of Stanford University. Species having a cosmopolitan distribution are not so treated. In preparing these ranges of species, a series of notes made by Dr. Gilbert, which he has kindly placed in our hands, has been of great assistance, and has added materially to our knowledge of distribution of west-coast fishes.

We wish to thank Dr. C. H. Gilbert for making the trips to San Diego in 1902 and 1903 possible; Dr. W. E. Ritter and Dr. Fred Baker for making the trip of 1905 possible under the auspices of the Marine Biological Association of San Diego; and Dr. Baker especially for his hospitality and much aid in making collections.

Stanford University,
September 15, 1906.

Family BRANCHIOSTOMIDÆ.

1. **Branchiostoma californiense** Gill.

CALIFORNIA LANCELET.

(Jordan and Evermann, 1896, I, p. 4.)

The California lancelet has recently been taken in large numbers near Ballast Point, San Diego Bay, off the Coronado Islands, and in the inner harbor of San Pedro.

Family EPTATRETIDÆ.

2. **Eptatretus stouti** (Lockington).

THE HAG FISH.

(Jordan and Evermann, 1896, I, p. 6.)

This species was commonly taken in deep water off San Diego. It is known northward to Cape Flattery (Gilbert, 1893, p. 395), and is abundant in Monterey Bay. It has not before been recorded at San Diego.

Family HETERODONTIDÆ.

3. **Heterodontus francisci** (Girard).

BULL-HEAD SHARK.

(*Gyropleurodus francisci.* Jordan and Evermann, 1896, I, p. 20, fig. 9.)

This species is rather common south of Point Conception, and was frequently taken in San Diego Bay. The following description is of a specimen 795 millimeters in length, from San Diego:

Width of head equal to space between posterior tip of first dorsal and front of second dorsal. Distance between supraorbital ridges above middle of eyes equal to base of second dorsal. Anterior slope of pectoral exceeding posterior margin of pectoral in length by twice the diameter of orbit. Anterior slope of second dorsal equal to that of ventral or anal. Base of anal equal to that of first dorsal without spine, which forms rather more than half

the base of the latter. Insertion of anal directly below a point midway between posterior end of base and posterior angle of second dorsal. Inner angle of ventral ending directly below front of second dorsal spine. Pectoral when folded back reaching to below posterior tip of first dorsal, or to one diameter of eye of insertion of ventrals. Anterior slope of lower caudal lobe somewhat exceeding posterior margin of caudal below the notch, and equal to the anterior slope of first dorsal. First dorsal spine equal in length to the second, but much stouter. The black spots on body very sparse, not nearly so abundant as in smaller specimens.

In a specimen ten inches long the supercciliary ridges extend very much above the interorbital plane, thus making the interorbital space very concave. The spines before the dorsals are covered for three-fourths of their length by the skin. The shagreen spinules are rather sparsely scattered over the skin, leaving smooth interspaces. Larger spinules are irregularly scattered over the body among the smaller ones, being thickest along the back and upper part of sides. On the interorbital space they are definitely arranged in two rows following the inner side of the supercciliary ridges. In the newly hatched young the larger spinules only are present. The type of this species came from Monterey, but it is doubtless rare there, as it has not since been noticed.

Measurements.

Along median dorsal line:	mm.
From tip of snout to between front of eyes	53
To posterior edge of eyes	16
To between first gill openings	44
To between front of pectorals	25
To front of dorsal	78
To posterior end of dorsal base	70
To posterior tip of dorsal	48
To front of anal	34
To front of second dorsal	89
To posterior end of second dorsal	60
To tip of second dorsal	39
To tip of caudal	240
Total length	795

Family SCYLLIORHINIDÆ.

4. **Catulus uter** Jordan and Gilbert.

SWELL SHARK.

(Jordan and Evermann, 1896, I, p. 25, fig. 12.)

This small shark is common in the Santa Barbara Channel, and is often taken in the traps set for spiny lobsters. It has the peculiar habit of inflating its stomach with air like a globe fish when caught. It has been recorded at Monterey by Jordan and Gilbert (1880, p. 458).

Family CARCHARIIDÆ.

5. **Mustelus californicus** Gill.

DOG SHARK.

(*Galeus californicus* Jordan and Evermann, 1896, I, p. 30.)

This is the commonest shark in Southern California, great numbers being taken in seines and on set-lines in San Diego Bay.

From the 20th of May (the date of our arrival in 1905) to the middle of June, this species was comparatively scarce. Though set-lines were continually used, only thirty specimens were taken, all of which were females. After the latter date, large numbers were taken, the males being well represented.

This species closely resembles *Cynias lunulatus,* of the coast of Lower California and southward. It differs from it in having a shorter, more rounded snout, a less angulated mouth, a more anterior first dorsal, a shorter pectoral, and the apex of the first dorsal more anterior to its posterior tip. The differences of the shorter snout and broader mouth appear much greater than actual measurements indicate.

The distance from the tip of the snout to the insertion of the pectoral is contained from 5⅕ to 5⅗ in the entire length to the tip of the caudal in *Mustelus californicus,* while in *Cynias lunulatus* it is from 4⅔ to 4¾. The snout measured obliquely across top of head to eye is contained from 4 to 4½ in distance from tip of snout to first dorsal in the former species; in *C. lunulatus* it is

from 3½ to 3⅔. The distance from the insertion of the ventral to a point vertical from the insertion of the first dorsal is from 6½ to 7⅗ in the body, while in *C. lunulatus* this distance is from 5⅔ to 6⅖. The vertical from the middle of the first dorsal falls nearer the ventral than the pectoral in *M. californicus,* and midway between these points in *C. lunulatus.* The anterior margin of the first dorsal when laid close to the back does not reach the posterior tip of the dorsal by a distance equal to the diameter of the eye. In *C. lunulatus* it does not reach the same point by half the eye.

The male of *M. californicus* has a longer, sharper snout than the female, and the distance between the angles of the mouth is less. Occasionally these sexual differences do not appear, but they are usually very evident. The individual variation in outline of snout is great in both male and female, ranging from a continuous blunt curve to a decided angle, approaching, but not invading, the range of variation of *C. lunulatus.*

The above measurements were drawn from about sixty specimens of *M. californicus,* and five specimens of *C. lunulatus.*

This shark has been noticed as far north as San Francisco by Jordan and Gilbert (1880, p. 458). It is rare northward.

6. **Rhinotriacis henlei** Gill.

(Jordan and Evermann, 1896, I, p. 31.)

This shark has been once taken in San Diego Bay by Dr. C. H. Eigenmann (1892, p. 133). It is apparently more common northward than has hitherto been supposed, as about fifty specimens were recently sent from the San Francisco markets to Stanford University for dissecting purposes. The species has doubtless been passed over as *Mustelus californicus* Gill, which it much resembles. It may be known at once, however, by the sharper, cusp-bearing teeth. It has been recorded at Humboldt Bay by Jordan and Gilbert (1881, p. 31).

The type of the species had probably been born but a short time when collected, as an example taken from the oviduct of one of our specimens is of the same size, 9½ inches in length, and agrees very well with the original description (Gill, 1862*a*, p.

486). In the description of the type the distance from the tip of the snout to the ventrals is given at 33 hundredths of the length. This is evidently a slip of the pen, and should read 43 hundredths.

7. **Triakis semifasciatus** Girard.

THE LITTLE LEOPARD SHARK.

(Jordan and Evermann, 1896, I, p. 31.)

This shark is much more common in the summer than in the winter in San Diego Bay. The following description was taken from a specimen 23 inches in length.

Head 6⅗ in total length; eye 7½ in head, measured obliquely across top of head from tip of snout to first gill opening; cartilage of interorbital space 2¼; width of mouth 3; distance from tip of snout to border of lip 3⅕; distance from front of first dorsal to front of second equal to the distance of first dorsal from tip of snout, or contained 3⅓ times in total length; distance from base of second dorsal to tip of tail 3⅙ in length; dorsal slope of caudal 4⅗.

The ground color is gray or dove color, growing white below; a golden shade follows the middle of side. Back with broad black cross-bars extending down to middle of sides about equal in width to the interspaces. Narrower bars on top of head; one on snout following its contour; a straight one connecting eyes; one connecting posterior corners of eyes: a wider one at nape; a still wider one, as wide as the succeeding ones, opposite insertion of pectorals. One opposite inner posterior angle of pectorals; the next under anterior third or dorsal, running up on fin nearly to its edge, but not connecting with its opposite half. One under posterior end of dorsal involving base of fin; the next above base of ventrals; the next midway between the last and the succeeding one, which is under the anterior end of second dorsal, meeting its opposite half over the edge of fin. One under the posterior end of second dorsal involving base of fin; one opposite tip of anal, and three equally spaced on upper edge of caudal. A series of large spots along lower part of side anterior to ventrals, alternating with the cross-bars. Posterior to the nape there is a spot at the median dorsal line between each bar; one of them at the

anterior end of each dorsal, and one at the base of dorsal. There is a small round spot at the middle of each dorsal, or sometimes two on the first. Two rather indistinct ones on the pectoral; one on the ventral; and two on the lower caudal lobe.

This shark is found northward to San Francisco. It is easily known by its color.

8. **Galeus zyopterus** (Jordan and Gilbert).

SOUP-FIN SHARK

(*Galeorhinus zyopterus* Jordan and Evermann, 1896, I, p. 32, fig. 15.)

Very abundant on the Southern California coast. The following description is of a specimen 5 feet 4 inches in length.

Head to first gill opening 4½ in length to base of caudal. Width of mouth between outer angles 1 1/10 in distance from mouth to tip of snout. Distance between inner angle of nostrils 2 in same space. Upper labial groove equal in length to long diameter of eye; lower groove three-fifths as long. Tip of lower jaw reaching to below a point half a diameter of eye in front of eye. Eye 4½ in snout; nictitating membrane well developed, capable of entirely closing eye in fresh specimens. Spiracle half a diameter of eye behind eye. Interorbital space from edge of eyelids 1⅛ in snout.

Anterior slope of pectoral greater than posterior slope by three-quarters of the diameter of eye, or contained 2¼ times in the distance from front of pectoral to tip of snout. Tip of pectoral reaching to anterior fourth of base of dorsal. Front of first dorsal equidistant from front of snout and front of second dorsal. Anterior slope of first dorsal equal to distance from tip of snout to middle of eye. Base and posterior slope of first dorsal equal in length, and as long as snout. Anterior and posterior slope of second dorsal about equal, and contained 2⅙ in snout. Front of ventral nearer to base of first dorsal than to base of second by a distance contained 3 times in length of snout. Length of caudal along upper margin contained 4 9/10 in entire length to tip of caudal; lower caudal lobe along anterior margin equal in length to snout and eye. Ventral and anal opposite to each other, the

latter somewhat smaller. Fourth gill opening above anterior part of pectoral. No black on fins.

This specimen had 28 eggs, 14 in each oviduct, each about 4 inches long and covered with a thin brownish membrane.

This shark is found in abundance northward to San Francisco (Jordan and Gilbert, 1880, p. 458). It reaches a length of 6 feet, and is of some value for the oil which its liver yields, but more particularly for its fins, from which the Chinese make a finely flavored soup, the cartilaginous fin-rays dissolving into a nutritious gelatine. Most of the fins on the market are used by Chinese in the United States, but some of them are shipped to China.

9. **Prionace glauca** (Linnæus).

BLUE SHARK.

(Jordan and Evermann, 1896, I, p. 33, fig. 16.)

Recorded from San Diego by Eigenmann (1892, p. 133). Not seen by us. The blue shark is occasionally taken on our coast. It is abundant in tropical seas, and not uncommon in British waters. It reaches a length of 15 to 20 feet, and shares with most large sharks the reputation of being a man-eater.

10. **Carcharias lamiella** Jordan and Gilbert.

BAY SHARK.

(Jordan and Evermann, 1896, I, p. 37.)

San Diego Bay is the type locality of this shark, where it is a rare species. It is the only species of *Carcharias* occurring on our coast. Dr. Jordan has a photograph of this shark from Avalon, Santa Catalina Island.

Family SPHYRNIDÆ.

11. **Sphyrna zygaena** Linnæus.

THE HAMMER-HEADED SHARK.

(Jordan and Evermann, 1896, I, p. 45.)

Occasionally taken south of Point Conception. A mounted specimen seen that was taken off Point Loma. It is of cosmopolitan distribution, being found in all warm seas. It reaches a length of 15 feet.

Family ALOPIIDÆ.

12. **Alopias vulpes** (Gmelin).

THE THRESHER SHARK.

(Jordan and Evermann, 1896, I, p. 45, fig. 20.)

Not uncommon on the Southern California coast. It is found in all warm seas.

Family SQUALIDÆ.

13. **Squalus sucklii** (Girard).

THE DOG FISH.

(Jordan and Evermann, 1896, I, p. 54.)

Reported by the fishermen to be rather abundant in deep water a few miles from the mouth of San Diego Bay. Unlike specimens from the north, it is unknown from the bays or shallow water. Two specimens secured. It is found northward to Bering Island (Jordan and Gilbert, 1899, p. 434), and is very abundant north of San Francisco.

Family SQUATINIDÆ.

14. **Squatina squatina** (Linnæus).

THE ANGEL SHARK.

(Jordan and Evermann, 1896, p. 58.)

Not uncommon: specimens frequently seen moving slowly over the bottom apparently in search of food. It is widely distributed over all warm seas, and is found northward to San Francisco on our coast.

Family RHINOBATIDÆ.

15. **Rhinobatus productus** Ayres.

GUITAR FISH.

(Jordan and Evermann, 1896, I, p. 63.)

This species is very abundant in rather shallow water. Large numbers were taken in San Diego Bay. The following description was drawn from a male specimen 35 inches in length:

Width of snout at front of eyes equal to distance from tip of snout to between posterior edge of spiracles, or three times interspiracle width. Interorbital cartilage contained 4¼ times in same distance. Rostral ridges running parallel and rather close together along their anterior half. Width of mouth contained 2$^{1}/_{10}$ in distance from tip of snout to between anterior edge of nostrils. Least width between nostrils 4⅘ in same distance. Width of body at posterior angle of pectorals equal to distance from tip of snout to margin of orbit. Distance across pectorals 1¾ in distance from tip of snout to first dorsal. Anterior slant of dorsals equal, and contained 1¾ in snout to posterior edge of spiracles. Very conspicuous lateral folds along lower side of body. Claspers reaching nearly to opposite front of first dorsal. Shagreen at tip of snout, around front of orbit, and posterior inner edge of spiracles enlarged and polished. A narrow band of irregular spines along back, and a small bunch of humeral spines. No spines on rostral ridges. Larger specimens are somewhat broader.

Small specimens of about a foot in length have the spines on the back larger and sharper, and in addition have spines along the rostral ridges, and around the inner and anterior borders of the eye. A wide flat digitate flap is present on the upper surface of the tip of the snout in the young of both sexes, up to 15 or 16 inches in length. A female specimen 22 inches long has the rostral flap nearly absorbed, only the fringed posterior edge remaining; the rostral ridges are coarsely roughened. The position of the flap is marked in the adult of all ages by a transverse slit at the tip of the snout.

We may here call attention to the following mistakes occurring in the description by Jordan and Evermann. The rostral ridges are nowhere confluent, but are parallel along their anterior half. The rostral flap is not confined to the female, but is equally developed in the young of both sexes. The black spot under the tip of the snout is seldom present in the adult, but is nearly always in the young.

This species is found from San Francisco (Jordan and Gilbert, 1880, p. 458) to San Diego.

Measurements.

Along median dorsal line:	mm.
From tip of snout to between front of eyes	120
To posterior edge of spiracles	35
To tips of posterior pectoral lobes	185
To tips of ventral lobes	115
To front of first dorsal	45
To posterior tip of first dorsal	65
To front of second dorsal	100
To posterior tip of second dorsal	65
To tip of caudal	185
Total length	915

16. **Zapteryx exasperatus** (Jordan and Gilbert).

(Jordan and Evermann, 1896, I, p. 64.)

San Diego Bay is the type locality of this ray. The male specimens are reported by Eigenmann (1892, p. 134) to be abundant in the bay, though it was not seen by us; female specimens have never been taken.

17. **Platyrhinoides triseriatus** (Jordan and Gilbert).

(Jordan and Evermann, 1896, I, p. 65.)

One specimen taken at Newport Bay. It is said to be common, though it was not taken by us at San Diego. Recorded from San Francisco by Jordan and Gilbert (1880, p. 458).

Family RAJIDÆ.

18. **Raja rhina** Jordan and Gilbert.

THE SHARP-NOSED RAY.

(Jordan and Evermann, 1896, I, p. 72.)

A male specimen 40 inches in entire length was taken on the banks off Point Loma, and was reported by the fishermen to be not very rare. This is the first time this ray has been reported south of Monterey Bay.

Anterior edge of pectoral undulating; concave to opposite eye, where it is convex, thence concave to tip of snout. Tip of snout very acute; its width, a distance from its tip equal to width of interorbital space, is contained 1⅖ in interorbital space. Diam-

eter of ball of eye 7⅘ in snout in median line, and slightly greater than length of spiracle. Interorbital space 4 in length of snout; interspiracle space 3. Distance between inner angles of mouth contained 2⅓ in distance from mouth to tip of snout; distance between nostrils contained 2⅗ in same space. A line drawn between outer angles of pectorals exactly bisects a median longitudinal line reaching from tips of ventrals to a point midway between tip of snout and middle of eyes. Length of tail from inner angle of ventrals is contained 3 times in entire length. Distance from front of anterior dorsal to tip of tail, contained 6⅗ times in distance from anterior dorsal to tip of snout. The stellated area on snout extends to posterior edge of spiracles, and behind each spiracle is a small patch; the stellæ coarser anteriorly. A group of strong spines extending around front of eye and back on supraorbital ridge to opposite posterior edge of spiracle. These are very irregular in size and position, and can not be exactly counted, but there are at least 20 of them (from 5 to 7, Jordan and Evermann, I, p. 72). A group of spines on median line of back a short distance behind spiracles and in front of humeral arch. A median line of strong spines on tail, beginning opposite posterior edge of pectorals (not ventrals, as stated by J. and E). Smaller spines scattered irregularly over the surface of the tail,, and interspaced with still smaller ones. Edges of pectorals with small spines; larger and more close set along anterior edges. A wide stellated area on median line of back behind humeral arch. Bases of pectorals and median part of back perfectly smooth. The ocellated spot of the young on the base of the pectoral represented by a dusky diffused blotch.

This species is found northward to Vancouver Island (Jordan and Gilbert, 1881, p. 34).

19. **Raja inornata** Jordan and Gilbert.

COMMON SKATE.

(Jordan and Evermann, 1896, I, p. 73.)

Recorded southward to Santa Barbara. Fishermen report a skate frequently taken on the banks off Point Loma, having a shorter snout than *Raja rhina*, possibly this species. It is known north to San Francisco.

Family DASYATIDÆ.

20. **Urolophus halleri** Cooper.

THE ROUND STING RAY.

(Jordan and Evermann, 1896, I, p. 80.)

The commonest sting ray of San Diego Bay. They are a great pest to fishermen working in the bay, as they cut nets and lines and much time is wasted in disentangling them from seines. Fishermen never fail to kill them when caught, though their numbers doubtless make them one of the most valuable scavengers.

A couple of embryos nearly three inches long taken from the oviduct of an adult, have a conspicuous flap extending back from the eye and the upper edge of the spiracle and ending in a rather long free point behind.

Some specimens are dark brown on the entire upper surface, profusely spotted with clear-cut, round, light yellow dots, smaller than a pin head, which are indistinctly ringed with brown darker than the body color. Other specimens (the more usual coloration) have the spots more indistinct, blended, and many of them run together, making short reticulated marks. Still other specimens are uniform slaty brown above, without a trace of spots. Sometimes specimens have large, light, blended spots, as large in diameter as the combined length of the eye and spiracle, and with or without the small spots. Ventral surface white medially, growing orange or red towards edge of fins and on caudal peduncle. Extreme edge of fins and lower surface of caudal peduncle sometimes light brown, and with or without small, light spots. Known from Santa Barbara (Jordan and Gilbert, 1880, p. 457) southward probably to Panama (Gilbert and Starks, 1904, p. 15).

21. **Dasyatis dipterura** Jordan and Gilbert.

THE RAT-TAILED RAY.

(Jordan and Evermann, 1896, I, p. 85.)

This species is not uncommon, though taken by us less frequently than any other of the sting rays. The smaller specimens are perfectly smooth; a specimen 29 inches in length had four

spines along the median dorsal line, but no humeral or other spine. A specimen 37 inches in length had a single small spine at the upper end of each humeral arch, and 8 similar spines in front of them, occupying a space as long as spiracle. The width of the disk was equal to its length from tip of snout to end of ventral fins. It is recorded only from San Diego.

22. **Pteroplatea marmorata** Cooper.

THE CALIFORNIA BUTTERFLY RAY.

(Jordan and Evermann, 1896, I, p. 87.)

This sting ray is very common on the warm, shallow tide flats. The following description was drawn from a specimen 22 inches in length.

Width from vertebral ridge to outer angle of pectoral equal to length of body from front of eyes to posterior edges of pectorals. Distance along anterior margin of disk from tip of snout to outer angle of pectoral equal to distance from tip of snout to posterior end of ventrals. Interorbital space equal to length of snout; diameter of eye 3½ in interorbital space. Width of mouth equal to distance between outer angles of nostrils, and slightly greater than interorbital space. From tip of snout to mouth 3½ in distance from mouth to vent. Length of ventral from posterior angle of pectoral equal to width of interorbital space. Length of tail equal to length of snout and eye; sting inserted opposite posterior end of ventrals.

Color in life: Dark brown everywhere, mottled with small light drab spots and reticulated lines. Belly and front of under parts white; pectorals yellow, covered with dark reticulations. Under side of tail and claspers and posterior half of ventrals clear warm yellow.

The outer angle of pectorals moves farther forward with age. In a specimen 4 feet wide, a line drawn between the outer angles of pectorals crosses the median dorsal line at a point midway between the posterior edge of the ventrals and the front of the eyes. In a specimen 22½ inches wide, this line falls midway between the edge of the ventrals and the posterior edge of the spiracles. In a specimen 12 inches wide it is midway between the ventrals

and a point behind the spiracles, a distance equal to one diameter of the eye. In a specimen 6½ inches wide the line crosses at a point midway between the edge of the ventrals and a point behind the spiracles, a distance equal to three times the diameter of the eye.

Known from Santa Barbara (Jordan and Gilbert, 1880, p. 457) to San Bartolomé Bay, Lower California.

MEASUREMENTS.

Along median dorsal line:	mm.
From tip of snout to between front of eyes	113
To between posterior of eyes	20
To between posterior part of spiracles	32
To inner angle of pectorals	475
To tip of ventrals	90
To tip of spine	25
To tip of tail	55
Total length	810

Along median dorsal line:	mm.
From tip of snout to mouth	120
To vent	500
To tip of ventrals	110
To tip of tail	80
Interorbital width	120
Interspiracle width	110
Entire width	1400

Family AËTOBATIDÆ.

23. **Aetobatus californicus** Gill.

BAT-FISH.

(*Myliobatus californicus* Jordan and Evermann, 1896, I, p. 89.)

Very abundant on the shallow mud-flats. On two occasions in the early summer adult females gave birth to young during their struggles after they had been caught and thrown on the beach. Five were born to one, and six to the other. They resembled the adults in nearly all proportions, except that the tail was longer. They were each about 9 inches in width, and the umbilical cord was wholly absorbed. This ray is found northward to San Francisco (Jordan and Gilbert, 1880, p. 457).

Measurements.

Along median dorsal line:	mm.
From tip of snout to between front of eyes	65
To between posterior edge of eyes	29
To posterior edge of spiracles	41
To posterior angle of pectoral	290
To tip of pectoral	57
To front of dorsal	32
To end of dorsal	28
To base of caudal spine	15
To tip of spine	62
To tip of tail	365
Total length	984

Width of disk, 766 mm.; interspiracle width, 102; length of ventral from inner angle of pectoral, 115; tip of snout to edge of upper lip, 63; width of mouth (upper lip), 52.

Family CHIMÆRIDÆ.

24. **Chimaera colliei** Lay and Bennett.

THE RAT FISH.

(*Hydrolagus colliei* Jordan and Evermann, 1896, I, p. 95, fig. 41.)

This species is not uncommon a few miles off shore from the mouth of San Diego Bay. It has not before been recorded this far south. Unlike examples from the north, it is unknown from the bays or shallow water. The San Diego Natural History Society has several specimens preserved. It is known northward to Puget Sound (Jordan and Starks, 1895, p. 789).

Family MURAENIDÆ.

25. **Rabula aquae-dulcis** (Cope).

(Jordan and Evermann, 1896, I, p. 390.)

A specimen in the U. S. National Museum said to have been taken at San Diego by Dr. J. G. Cooper. This is probably an error in labeling. The only other known specimen is the type from Costa Rica.

26. **Gymnothorax mordax** (Ayres).

CONGER EEL.

(*Lycodontis mordax* Jordan and Evermann, 1896, I, p. 395).

Common; frequently brought in by the fishermen. Specimens taken in rock pools at La Jolla. Fresh specimens have the tip of

the tail bright orange or scarlet, and the head a lighter brown than the body. This eel reaches a length of 5 feet, and is found in abundance south of Point Conception. Its flesh is fat, resembling that of the common fresh-water eel of the eastern United States, and when fried is said to be very palatable.

Family ELOPIDÆ.

27. **Albula vulpes** (Linnæus).

THE LADY FISH.

(Jordan and Evermann, 1896, I, p. 411, fig. 179.)

Several larval and young specimens, from 2 to 5 inches long, taken at San Diego from May 15 to June 15. Fishermen report the occasional capture of an adult specimen in the bay. Two specimens 15 inches in length, recently taken in sardine nets by fishermen in Monterey Bay, and secured by Mr. F. A. Woodworth, extends the northern range of this species. It is almost universally distributed throughout warm seas, and is abundant in Hawaii and Japan. It reaches a length of 3 feet and is said to be a food fish of good quality.

Family CLUPEIDÆ.

28. **Etrumeus micropus** (Schlegel).

(*Perkinsia othonops* Jordan and Evermann, 1896, p. 420).

The type of *Perkinsia othonops* Eigenmann, taken at San Diego, is the only specimen known from America. It is not uncommon in Japanese waters.

29. **Clupea pallasii** Cuvier and Valenciennes.

HERRING.

(Jordan and Evermann, 1896, I, p. 422, fig. 186).

The herring is known in abundance from Bering Sea to San Diego. It is abundant in the Bay of San Diego in the winter time, spawning about January. It reaches a length of about 18 inches.

30. **Sardinella caeruleus** (Girard).

CALIFORNIA SARDINE.

(*Clupanodon caruleus* Jordan and Evermann, 1896, I, p. 423.)

Abundant on the Southern California coast, and valued chiefly as bait, though an excellent food fish. Specimens in our collection agree with the original description in having 19 dorsal rays, not 14 as stated by Jordan and Evermann. It is less than a foot in length, and is found northward to Puget Sound (Jordan and Starks, 1880, p. 790), and southward to Cerros Island.

Family ENGRAULIDÆ.

31. **Anchovia compressa** (Girard).

(*Stolephorus compressus* Jordan and Evermann, 1896, I, p. 447.)

This species is very abundant in San Diego Bay. The anal has 31 or 32 rays, which agrees with the description by Jordan and Evermann, but is less than the number given by Girard (1858, p. 336) for the typical specimens (anal, 2, 35–1).

Anchovia compressa differs from *A. panamensis* and *A. mundeola* in having a shorter head, a longer maxillary, and more gill rakers on upper limb of branchial arch. *A. compressa* has from 20 to 22, *A. panamensis* from 16 to 18, and *A. mundeola* 16 to 20.

This anchovy is found from Santa Barbara to the Gulf of California (Gilbert, MS. notes), and reaches a length of 5 or 6 inches.

32. **Anchovia delicatissima** (Girard).

(*Stolephorus compressus* Jordan and Evermann, 1896, I, p. 444.)

Equally abundant with *Anchovia compressa*, but far surpassing that species as a food fish in the richness and delicacy of its flesh. It may be at once known by its plumper, less compressed body, and narrower silvery lateral band. Specimens taken at Newport Bay and San Diego. Its southern range is not known.

33. **Engraulis mordax** Girard.

CALIFORNIA ANCHOVY.

(Jordan and Evermann, 1896, I, p. 448.)

Specimens from San Diego, and from Albatross stations 4324 and 4498 shows a wide range of variation. The head is contained

from 3 to 3¾ times in the length of the base of the caudal, the maxillary from 4¼ to 5⅔ times in the same distance, and the eye from 4 to 4½ times in the head. The dorsal has 14 or 15 rays, occasionally as many as 18; the anal has from 21 to 23.

Contrary to statements in current descriptions, specimens in alcohol, especially those that have lost their scales, show a very distinct silvery lateral band.

This is the largest and most valuable as a food fish of our anchovies, reaching a length of 7 inches, and extending its range northward to Puget Sound.

Family SYNODONTIDÆ.

34. **Synodus lucioceps** (Ayres).

LIZARD FISH.

(Jordan and Evermann, 1896, I, p. 539.)

This species is represented in the collection by two adult specimens from San Pedro, and a young one from San Diego.

In our specimens the lower jaw is not longer than the upper as stated by Ayres (1855, p. 69); they otherwise agree in essential respects with the original description.

In the young specimen, 1¼ inches in length, dark plates are present beneath the skin on the ventral side of the body, arranged as follows: One pair at edge of shoulder girdle, another pair midway between pectorals and ventrals, and five pairs between ventrals and vent. A dark line of pigment spots at base of caudal, and a few similar spots along middle of sides posteriorly.

This species reaches a length of 18 inches and ranges north to San Francisco (Jordan and Gilbert, 1880, 475). It is not uncommon, but is seldom brought to market.

Family MYCTOPHIDÆ.

35. **Macrostoma angustidens** Risso.

(Jordan and Evermann, 1896, I, p. 555.)

Known on our coast only from Cortez Banks. It is known from the Atlantic and Indian oceans, and Mediterranean Sea. Probably more than one specimen is confused under this name, and further study will modify this range.

36. **Lampanyctus townsendi** (Eigenmann and Eigenmann).

(Jordan and Evermann, 1896, I, p. 558.)

Known from Cortez Banks; the type was taken at a depth of 45 fathoms.

37. **Nannobrachium leucopsarum** (Eigenmann and Eigenmann).

(Jordan and Evermann, 1896, I, p. 562.)

This species is found rather abundantly in deep water from Alaska (Gilbert, 1893, p. 399) to San Diego. Eigenmann (1892, p. 142) reports it to be one of the most abundant Myctophids off Point Loma, especially during stormy weather, when it may be found in the stomachs of rockfish.

38. **Diaphus theta** Eigenmann and Eigenmann.

(Jordan and Evermann, 1896, I, p. 564.)

This species is known from the coast of Washington (Gilbert, 1893, p. 399) to San Diego (the type locality) in deep water.

39. **Myctophum californiense** Eigenmann and Eigenmann.

(Jordan and Evermann, 1896, I, p. 572.)

Cortez Banks; known only from the types.

40. **Tarletonbeania crenularis** (Jordan and Gilbert).

(Jordan and Evermann, 1896, I, p. 575.)

This specimen is known only from two specimens, one taken from the stomach of an albacore in the Santa Barbara Channel (the type), the other blown on the deck of a vessel on the coast of Washington during a storm (Jordan and Evermann, *l. c.*).

41. **Tarletonbeania tenua** Eigenmann and Eigenmann.

(Jordan and Evermann, 1896, I, p. 575, fig. 248.)

Known only from the type from the stomach of *Sebastodes miniatus* taken near the Coronado Islands.

Family PLAGYODONTIDÆ.

42. **Plagyodus ferox** (Lowe).

(*Alepisaurus asculapius,* Jordan and Evermann, 1896, I, p. 595, fig. 258.)

A specimen 48 inches in length in the collection of the San Diego Natural History Society.

Head 5¾ in length to base of caudal; depth at occiput equal to length of snout. Eye between adipose eyelids 6½ in head; snout to edge of adipose eyelid 2⅓; maxillary 1⅖; mandible 1⅓; interorbital space 2¼ in snout; dorsal 37; anal about 16 (some rays missing); ventral 11, counting a very short first ray.

Snout pointed; jaws equal. Maxillary not free, the skin of side of head continuous over it; it ends at corner of mouth, which is one diameter of pupil distant from preopercular ridge. All teeth inclined backward; 2 enlarged teeth at front of mandible on each side; the anterior one a little more than half the size of the other. Behind them 4 or 5 small sharp canines, their length about a third of diameter of pupil; then 2 or 3 (2 on one side, 3 on the other) stout, sharp canines, which are the largest in the lower jaw, their length nearly half the diameter of eye; following are 11 short, triangular teeth like the teeth of a saw; their posterior edges nearly verticle, their anterior edges oblique. Premaxillary with a row of very small sharp canines anteriorly, which grow gradually much smaller posteriorly. No vomerine teeth. A large canine on palatine situated under a point half way between tip of snout and front of eye; a larger similar one under a point at posterior seventh of snout; behind them a toothless space back to below anterior orbital rim, followed by 8 or 10 saw-like teeth similar to those on lower jaw. Skin of side of head in front of preorbital ridge thin, smooth, and without ridges or wrinkles.

A line of pores runs down across cheek from top of head, turning forward beneath eye and running half way to tip of snout. Opercle and subopercle with sharp conspicuous ridges, radiating from points at their anterior edges, a faint indication of striæ following posterior outline of bones. Mandible with similar ridges diverging backward from a point at tip of dentary,

and forward from a point at posterior end of articular. Gill rakers sharp and single pointed on anterior part of lower limb of arch; double on posterior part, and on upper limb of arch; their number 6 + 19; branchiostegals 7.

Only a few of the dorsal spines are entire; the fourth is 1 1/10 in head; the tenth is 1 1/4; the seventeenth 1 1/4; and the thirtieth 2. Base of adipose dorsal equal to diameter of eye; its height slightly exceeds the length of its base; its distance from upper caudal rays is contained 1 1/4 in head. Origin of anal from base of lower caudal rays exceeds the length of the head by one diameter of the eye. Pectoral sharply pointed posteriorly; its length 1 1/4 in head; its rays much divided, 13 in number. Ventrals reaching slightly past vent; their length 3 1/10 in head; caudal deeply forked. Vent midway between tip of mandible and base of median caudal rays.

Color, dark brown on back, creamy brown on sides, running to white below. Head almost entirely silvery. A conspicuous dark brown streak along lateral line. Dorsal and adipose dorsal uniform dark brown; pectorals silvery, slaty black at tips, their inner surface brown; ventrals brown; caudal lobes brown toward tips; anal silvery.

This species is known northward to Unalaska (the type locality of *Plagyodus asculapius*) and in deep waters of the Atlantic. Most of the specimens known have been cast ashore by storms.

Family PARALEPIDIDÆ.

43. **Sudis ringens** Jordan and Gilbert.

(Jordan and Evermann, 1896, I, p. 600.)

"Santa Barbara Channel, California, the only specimen known taken from the stomach of a hake (*Merluccius*), itself found in the stomach of a long-finned albacore (*Germo alalunga*)." (Jordan and Evermann, *l. c.*)

Family PŒCILIIDÆ.

44. **Fundulus parvipinnis** Girard.

(Jordan and Evermann, 1896, I, p. 640.)

Very abundant on the Southern California coast, especially

in San Diego Bay. Known southward to Magdalena Bay, Lower California (Gilbert, MS. notes).

Loving the warm shallow water of the sand beaches, they may be seen in small schools on bright sunny days in San Diego Bay, so close to the shore that their backs appear above the water, and the little waves frequently roll them high and dry on the sand, from which they quickly struggle into the water again.

Family BELONIDÆ.

45. **Tylosurus exilis** (Girard).

NEEDLE FISH.

(Jordan and Evermann, 1896, I, p. 714.)

Common on the Southern California coast. The following description of color was taken from a fresh specimen.

Back clear Venetian green, with a distinct narrow lateral band of darker green, having bluish reflections running back just above base of pectoral, and becoming indistinct posteriorly. Sides and lower parts bright silvery, with lilac and violet reflections. Pectorals slightly dusky; ventrals white; anal white except a pinkish area on first one or two rays. Dorsal a delicate but conspicuous blue, its anterior lobe tipped with pinkish red; median rays of caudal blue, the lobes pinkish red toward tips.

This species reaches a length of 3 feet, and is common from Point Conception south to Guaymas, Mexico.

Family HEMIRAMPHIDÆ.

46. **Hyporhamphus rosae** (Jordan and Gilbert).

HALFBEAK.

(Jordan and Evermann, 1896, I, p. 721.)

Rather common in San Diego Bay; the largest specimen taken was 7½ inches long. It is found southward along the Lower California coast to Guaymas, Mexico (Evermann and Jenkins, 1891, p. 135).

Family SCOMBRESOCIDÆ.

47. **Cololabis brevirostris** (Peters).

(Jordan and Evermann, 1896, I, p. 726.)

The adult of this species has been very rarely taken on the California coast. It occurs northward to Tomales Bay (the type locality), though the young has been recently found in abundance by the U. S. S. Albatross. It is very close to, if not identified with, *Coloabis saira*, a species occasionally found in large schools in Japan. Recorded from San Diego by Eigenmann (1892, p. 143).

Family AULORHYNCHIDÆ.

48. **Aulorhynchus flavidus** Gill.

(Jordan and Evermann, 1896, I, p. 754.)

This species is known on the Southern California coast only from San Nicholas Island (Gilbert, MS. notes). Its range extends northward to Sitka, Alaska (Bean, 1881, p. 240).

Family EXOCŒTIDÆ.

49. **Cypselurus californicus** Cooper.

THE GREAT FLYING FISH.

(*Exocœtus californicus* Jordan and Evermann, 1896, I, p. 740, fig. 319.)

Two large specimens were preserved from off San Pedro. It is very abundant about the Santa Barbara and Coronado Islands. It disappears in winter and it is not known where it goes, as it has not been reported outside of California. It is probably the largest of the flying fishes, and the only one on our coast. It is said to be an excellent food fish.

Family SYNGNATHIDÆ.

50. **Syngnathus californiensis** Storer.

GREAT PIPE FISH.

(*Siphostoma californiensis*, Jordan and Evermann, 1896, I, p. 764.)

Two specimens were taken at San Pedro. It is known northward to Puget Sound (Jordan and Starks, 1895, p. 797), and

southward to San Bartolome Bay, Lower California (Gilbert, MS. notes). It has a longer dorsal than other Southern California pipe fishes; 39 to 46 on 1 + 9 rings.

51. **Syngnathus punctipinnis** (Gill).

(*Siphostoma punctipinne* Jordan and Evermann, 1896, I, p. 763).

Known only from the types taken at San Diego in 1862.

52. **Syngnathus leptorhynchus** Girard.

THE COMMON PIPE FISH.

(*Siphostoma leptorhynchus*, Jordan and Evermann, 1896, I, p. 764.)

Exceedingly abundant; several hundred were taken at one haul of the seine from among the eel-grass at low tide near the head of San Diego Bay, and specimens were taken in all parts of the bay at nearly every seine haul.

In January nearly all the brood-pouches were full of eggs in an advanced state of incubation; a very few were empty. At the middle of May some brood-pouches contained eggs, some contained young with the yolk sack still attached, and many contained young that were probably about ready to be expelled; so it is probable that the breeding season is extended over a large part of the year. This species is abundant northward to San Francisco Bay.

53. **Syngnathus auliscus** (Swain).

PIPEFISH.

(*Siphostoma auliscus*, Jordan and Evermann, 1896, I, p. 767.)

This species is generally distributed in San Diego Bay, but is not so common in salt water as *Syngnathus leptorhynchus*. In the sloughs which receive fresh water, however, it is apparently more common.

Specimens from San Diego and San Pedro agree fairly well with the description of the typical specimens (Swain 1882, p. 310), but show a greater degree of variation. The head is contained from 9 to 9¼ in the entire length without caudal; the dorsal has from 29 to 33 rays, and extends over 1 + 6, or 0 + 7.

or 1 + 7 rings; there are 14 or 15 body rings, and from 37 to 41 caudal rings (the ring containing the vent counted as a caudal ring); the caudal pouch covers from 20 to 24 rings.

This species differs from *Syngnathus leptorhynchus* in having the angles of the body sharper, the head shorter, the snout shorter, and with a more prominent median keel, the caudal pouch longer, and the body rings fewer. In the latter species the head is contained from 6½ to 8½ times in the length without caudal; the body rings number from 16 to 19; and the brood-pouch covers 19 to 20 rings.

It is known southward to Panama (Gilbert and Starks, 1904, p. 57); taken in Magdalena Bay (Gilbert MS. notes) and the Gulf of California.

54. **Syngnathus barbarae** (Swain).

(*Siphostoma barbaræ*, Jordan and Evermann, 1896, I, p. 765).

Only the type from Santa Barbara known.

55. **Syngnathus arctus** (Jenkins and Evermann).

SHORT-NOSED PIPEFISH.

(*Siphostoma arctum*, Jordan and Evermann, 1896, I, p. 771.)

Three specimens seined in San Diego Bay, and two taken in tide pools at La Jolla. They are the first that have been seen since the type was taken in the Gulf of California in 1888. The species has been erroneously recorded from Mazatlan (Jordan, 1895, p. 416).

Our specimens agree in all respects with the type which has been kindly loaned us by the U. S. National Museum.

The following color description was made from a male and a female specimen from San Diego Bay: Color, brown; a double row of dark spots along side back to vent; one on each plate. Belly ridge of female black; ridges on each side of pouch of male black. Ventral side of head anterior to a white transverse streak just behind eye marked with fine irregular cross streaks of white and brown in the female, with white dots in the male. At each angle behind vent, between each plate is a white dot (this is not evident in alcoholic specimens).

Specimens from La Jolla very much darker—almost black; under side of head blackish and without cross streaks.

MEASUREMENTS IN HUNDREDTHS OF LENGTH TO BASE OF CAUDAL.

	Type. Guaymas, Mexico.	La Jolla, Cal.		San Diego Bay.		
Length to base of caudal in mm.	89	77	82	85	74	58
Head in one-hundredths of length	9¼	10	9	9	9	10
Depth	4½	4½	4	4	4½	4
Length of snout	3½	3	3	3	3	2¾
Diameter of eye	2	2½	2¼	2	2¼	2½
Tip of snout to front of dorsal	35	34	33	32	34	35
Tip of snout to vent	34	33	34	33	33	35
Base of dorsal	8	9½	8	10	9½	9

56. **Hippocampus ingens** Girard.

CABALLITO DEL MAR.

(Jordan and Evermann, 1896, I, p. 776.)

San Diego is the type locality of this species, where it is very rare; not seen by us. It is found southward to Cape San Lucas (Gill, 1862, p. 282), and is one of the largest of the sea-horses, reaching a length of nearly a foot.

Family ATHERINIDÆ.

57. **Leuresthes tenuis** (Ayres).

(Jordan and Evermann, 1896, I, p. 802.)

Specimens taken in January and August at San Diego, the reported end and beginning of its residence in the bay. Its range extends northward to San Francisco (its type locality), where it is apparently rare.

58. **Atherinopsis californiensis** Girard.

PESCADO DEL RAY; "SMELT."

(Jordan and Evermann, 1896, I, p. 806, fig. 341.)

Common in San Diego Bay in January, when many large specimens were seined on the sandy beaches. It is said by Dr. Eigenmann (1892, p. 145) to enter the bay at the last of August

and remain till February. This and other Atherinoid fishes are unforunately almost universally known in southern California as smelt,—a fish they resemble only in being slender and silvery. It ranges northward to San Francisco.

59. **Atherinops affinis** (Ayres).

PESCADILLO DEL REY.

(Jordan and Evermann, 1896, I, p. 807, p. 342.)

This species was found in abundance in San Diego Bay from December to August, and unlike the other Atherinoid fishes it is said to be common in the bay all the year. It has been taken as far south as Magdalena Bay, Lower California (Gilbert, MS notes). It is known northward to San Francisco (type locality), and is abundant throughout its range.

60. **Atherinops insularum** Gilbert.

(Jordan and Evermann, I, 1896, p. 807.)

This is a species apparently confined to the islands from the Santa Barbara Islands to Guadalupe Island, replacing *Atherinops affinis* of the mainland.

It has fewer spines in the dorsal (5) than *Atherinops affinis,* finer scales (from 62 to 68), and a larger space between the dorsals. Dr. Gilbert (MS. notes) has records of its occurrence at the following localities: San Nicholas Island, Santa Cruz Island, San Clemente Island, Cerros Island, and Guadalupe Island.

Family MUGILIDÆ.

61. **Mugil cephalus** Linnæus.

MULLET.

(Jordan and Evermann, 1896, I, p. 811, fig. 343.)

Not uncommon in San Diego Bay, especially abundant in a brackish slough near Old Town. It is cosmopolitan in distribution.

Family SPHYRÆNIDÆ.

62. **Sphyraena argentea** Girard.

BARRACUDA.

(Jordan and Evermann, 1896, I, p. 826.)

Abundant in the open ocean, and the young are common in the bays in the spring-time. It is found from San Francisco to Guaymas, Mexico (Evermann and Jenkins, 1891, p. 137), and is a food fish of importance, especially southward.

Family POLYNEMIDÆ.

63. **Polydactylus opercularis** (Gill).

THREAD FISH.

(Jordan and Evermann, 1896, I, p. 830.)

Mrs. Andrews, an artist in San Diego, who has a large collection of oil studies and paintings of fishes, has a color study of what is apparently this species; she obtained two specimens from the fishermen. It has not before been recorded so far north; its range extends southward to Panama.

Family SCOMBRIDÆ.

64. **Scomber japonicus** Houttuyn.

MACKEREL.

(*Scomber colias* Jordan and Evermann, 1896, I, p. 866, fig 364.)

Very abundant on the Southern California coast. It is cosmopolitan in distribution, being known on both coasts of America northward to Maine and San Francisco, Japan, England, and the Mediterranean. It is a food fish of importance, but very inferior to the common mackerel of the east coast.

65. **Gymnosarda pelamis** (Linnaeus).

OCEANIC BONITO.

(Jordan and Evermann, 1896, I, p. 868.)

Mrs. Andrews, an artist in San Diego, has an oil-color study of this species. She secured the specimen in the local market. It

is a pelagic species found in most warm seas. On the Atlantic coast it has been taken as far north as Cape Cod, but it has not been recorded north of San Diego on the Pacific coast.

66. **Thunnus thynnus** (Linnaeus).

TUNNY; TUNA.

(Jordan and Evermann, 1896, I, p. 870.)

Rather abundant about the Santa Barbara Islands. It is a pelagic species found in all warm seas, and known northward on our coast as far as San Francisco. It is the largest of the bony fishes, reaching a weight of 1,500 pounds, though none of that size have ever been recorded on our coast. In the Santa Barbara Islands it is considered the king of game fishes, but it is unknown to anglers elsewhere. It is known as the Tunny on the Atlantic coast, and as the Tuna on our coast and in the Mediterranean.

67. **Germo alalunga** (Gmelin).

LONG-FINNED ALBACORE.

(Jordan and Evermann, 1896, I, p. 871, fig. 367.)

Abundant; a pelagic species widely distributed in warm and tropical seas, and found northward on our coast as far as San Francisco (Jordan and Gilbert, 1881, p. 45). It is very abundant about the Santa Barbara Islands, but is a food fish of little value, as its flesh is coarse.

68. **Germo macropterus** (Schlegel).

YELLOW-FIN ALBACORE.

Specimens have been in the last two years occasionally taken off Avalon. It is common in southern Japan and is occasionally taken about Hawaii. From *Germo alalunga* this species is known by the citron yellow finlets, and by the high soft dorsal and anal. (Jordan and Starks, 1906.)

69. **Sarda chilensis** Cuvier and Valenciennes.

BONITO.

(Jordan and Evermann, 1896, I, p. 872.)

Very abundant off Point Loma; ranging from Chili to Puget Sound. It is here recorded from the latter locality for the first

time, specimens having been taken in the winter of 1899 by the senior author. Eighteen gill rakers are attributed to the horizontal limb of the first branchial arch by Jordan and Evermann. They also describe the maxillary as not reaching the eye. There are eight or nine gill rakers, and the maxillary extends to the posterior border of the eye.

70. **Scomberomorus sierra** Jordan and Starks.

SPANISH MACKEREL.

(Jordan and Evermann, 1896, I, p. 874.)

Recorded by Eigenmann (1889, p. 126) from Cortez Banks under the name of *Scomberomorus maculatus*. It is known southward to Panama and the Galapagos Islands (Snodgrass and Heller, 1905, p. 361). Jordan and Evermann (1896, I, p. 874), under the description of *Scomberomorus maculatus*, state that the species is found on both coasts of North America. If *S. sierra* is a distinct species *S. maculatus* is confined to the Atlantic coast.

Family XIPHIIDÆ.

71. **Xiphias gladius** Linnæus.

COMMON SWORDFISH.

(Jordan and Evermann, 1896, I, p. 894.)

The fishermen at San Diego report this fish to be common in the summer time in the open sea. A specimen twelve feet in length was taken by the fishermen and put on exhibition in San Diego. Permission was obtained to describe it as it lay, but the anal and under parts could not be examined. It had been eviscerated and the depth much decreased.

Head from tip of mandible 4 in length to tips of middle caudal rays; sword from nostril 2¼. Width of sword opposite tip of mandible 2⅗ in post orbital part of head; at middle of sword ⅘ of diameter of eye. Mandible to posterior angle of mouth 3½ times diameter of eye. Eye 2⅔ in postorbital part of head. Interorbital space 11 in length to tips of middle caudal rays. Caudal keels very wide, the distance across them 5¾ in same distance; upper caudal lobe 5½; pectoral 4⅓. Height of anterior

dorsal slightly exceeds postorbital part of head and eye; that of posterior dorsal 4/5 of diameter of eye. Dorsal rays (not counting the rays enveloped in skin) 16–5.

The swordfish is widely distributed in the Atlantic, and is known on our Pacific coast north to the Santa Barbara Islands.

Family ISTIOPHORIDÆ.

72. **Tetrapterus mitsukurii** Jordan and Snyder.

THE MARLIN-SPIKE FISH.

(Jordan and Snyder, 1901, p. 304.)

This species is occasionally taken off Santa Catalina Island (Jordan and Starks, 1906). A specimen 12 feet long is on record at Avalon.

Family LEIDOPIDÆ.

73. **Lepidopus xanthusi** Goode and Bean.

(Jordan and Evermann, addenda III, 1898, p. 2843. The genus, 1896, I, p. 886.)

An adult specimen, 30 inches in length, has recently been taken at Avalon, Santa Catalina Island by Dr. C. F. Holder. (Jordan and Starks, 1906.) It is the first adult specimen collected, being previously known from two very small specimens taken at Cape San Lucas.

Family REGALECIDÆ.

74. **Regalecus russelli** (Shaw).

(Jordan, 1905, II, p. 472.)

A specimen recorded from Newport 22 feet in length, and others from Santa Catalina Island (Jordan and Starks, 1906).

Family CARANGIDÆ.

75. **Naucrates ductor** Linnæus.

PILOT-FISH.

(Jordan and Evermann, 1896, I, p. 900.)

A specimen of the pilot-fish recently recorded from off Santa Catalina Island (Jordan and Starks, 1906). It is a pelagic species widely distributed in all warm seas.

76. **Seriola dorsalis** (Gill).

YELLOW-TAIL.

(Jordan and Evermann, 1896, I, p. 902, fig. 380.)

Abundant on the Southern California coast. Known from Cape San Lucas (type locality) northward to the Santa Barbara Islands, where it is an important species.

77. **Caranx caballus** (Günther).

(Jordan and Evermann, 1896, I, p. 921.)

This species was recorded from San Diego by Girard (1858, p. 108), but it has not since been seen so far north. It is found southward to Panama and the Galapagos Islands (Snodgrass and Heller, 1905, p. 364).

78. **Trachurus picturata** (Bowdich).

HORSE MACKEREL.

(Jordan and Evermann, 1896, I, p. 909.)

Specimens taken in San Diego Bay. This species is of wide but peculiar distribution. It is known from Monterey to San Diego, from the Galapagos Islands to Chili, and New Zealand, but not from the west coast of Mexico and Central America. It is known from the Mediterranean, but not from the east coast of North or South America. It seems probable that further study will prove that more than one species is included in this range.

Family LUVARIDÆ.

79. **Luvarus imperialis** Day.

This species is recently recorded from off Catalina Island. (Jordan and Starks, 1906.) It is a widely distributed pelagic species.

Family LAMPRIDÆ.

80. **Lampris regia** (Bonnaterre).

OPAH; MOONFISH.

(*Lampris luna* Jordan and Evermann, 1896, I, p. 954.)

Mrs. Andrews of San Diego has a painting of this species from a specimen caught in the vicinity. It is a pelagic species cos-

mopolitan in distribution. There are two skins of the Opah at Avalon.

Family BRAMIDÆ.

81. **Brama raii** (Bloch).

POMFRET.

(Jordan and Evermann, 1896, I, p. 959.)

This species has been several times taken on the Southern California coast. A specimen seen from Santa Catalina Island. It is pelagic and widely distributed. On our coast it has been taken north to Vancouver Island (Jordan and Starks, 1895, p. 797). It has been commonly taken in Monterey Bay.

Family STROMATEIDÆ.

82. **Peprilus simillimus** (Ayres).

CALIFORNIA POMPANO.

(*Rhombus simillimus*, Jordan and Evermann, 1896, I, p. 967.)

Reported to be abundant at times, but not valued highly as at San Francisco. One small specimen seen at San Diego. This species is known northward to Puget Sound (specimens taken by Starks in 1899).

Family ICOSTEIDÆ.

83. **Schedophilus heathii** Gilbert.

(Gilbert, 1904, p. 260, pl. XXVI.)

One specimen 3½ inches in length taken at San Pedro. It is the second specimen known and resembles the type in all essential respects. Like the type, it was taken at the surfaee in company with a jelly-fish.

Family SERRANIDÆ.

84. **Sterolepis gigas** Ayres.

JEWFISH.

(Jordan and Evermann, 1896, I, p. 1137.)

Often abundant in deep water, especially about the Coronado Islands. The flesh is cured in brine and commands a high price. It is known northward to Monterey (Jordan and Gilbert, 1880, p. 456).

85. **Paralabrax nebulifer** (Girard).

JOHNNY VERDE.

(Jordan and Evermann, 1896, I, p. 1195.)

Not rare in San Diego Bay, though less common than *Paralabrax maculatofasciatus*. It may be known by the presence of small, round, dark spots confined to the head and caudal peduncle. It resembles *Paralabrax maculatofasciatus*, and differs from *Paralabrax clathratus* in its elongate third dorsal spine; its wide preorbital bone, which is equal in width to the diameter of eye; and its more rounded dorsal outline of head and snout.

All of the specimens examined by us have the second anal spine shorter than the third; not "as long as third," as stated in current descriptions.

Color in life: cheek and suborbital region with many small, round, golden, or yellowish brown spots. Ground color of back solid green to under middle of soft dorsal; behind this point the back and sides are reticuled with white. Under parts pure white. Three oblique, dusky bands under spinous dorsal, extending downward and backward across sides to belly. A wider, shorter, more vertical one under anterior third of soft dorsal, and the beginning of another just behind it; these extending a short distance up on soft dorsal. Dorsal and pectoral light transparent green; spinous dorsal dusky in front; upper part of caudal dark green, changing to blue below; ventral and anal a rather bright slaty blue.

The young are lighter than the adults, and have large, light spots on sides. The dark color along base of dorsal gradually extends down the sides with age.

It is known northward to Monterey (Jordan and Gilbert, 1880, p. 456), southward to Ascension Island, Lower California (Jordan and Gilbert, 1881*a*, p. 278).

86. **Paralabrax maculatofasciatus** (Steindachner).

SPOTTED CABRILLA.

(Jordan and Evermann, 1896, I, p. 1196, fig. 198.)

This is probably the commonest species of its genus in San Diego Bay. It may be readily known by its numerous dark

brown spots covering almost the entire body. It differs from *Paralabrax nebulifer* in having the scales on top of head extending forward to opposite middle of eyes instead of to opposite front of eyes as in the latter species.

The statement by Jordan and Evermann that the lower jaw does not project so far as in *Paralabrax nebulifer* is not true of any of the many specimens examined by us.

A specimen 19 inches in length has the third spine of the dorsal reaching to the base of the second ray of the soft dorsal.

This species is known from San Pedro (Jordan and Gilbert, 1880, p. 456), south to Mazatlan, Mexico (Jordan, 1895, p. 45).

87. **Paralabrax clathratus** (Girard).

CABRILLA.

(Jordan and Evermann, 1896, I, p. 1197.)

Though Dr. Eigenmann (1892, p. 150) reports the adult of this species to be "rarely if ever seen in the bay" (San Diego), we took several large specimens on set-lines at Roseville, finding it about as common as *Paralabrax nebulifer*. It may at once be known from other species of *Paralabrax* by the absence of small round spots on the body, in having the third, fourth, and fifth dorsal spines about equal in length, and the preorbital narrow, its width less than half that of the eye. The statement by Jordan and Evermann that the second anal spine is longer than the third is not true of any of our specimens, where it is equal to or shorter than the third.

The following color description was taken from a fresh specimen 19 inches in length:

Steel gray on lower half of sides; the scales along the middle of body dark on posterior edges. Back coal black with light areas indicating cross bars arranged as follows: a light spot under anterior dorsal rays; a wide light bar under middle of soft dorsal; and one under posterior end of soft dorsal. Sides and lower part of head yellowish; fins all tinged with yellow.

Small specimens from four to five inches in length are reddish brown on sides and back, with longitudinal rows of oblong, bluish, silvery spots forming broken streaks. A row on back fol-

lowing contour of lateral line; a row along lateral line; and a row running straight below lateral line from tip of opercular flap to middle of caudal peduncle, joining posteriorly the row along lateral line. Belly and lower parts silvery. An oblique red streak downward and backward across opercle and in front of pectoral base; another from eye turning downward and following edge of preopercle to its angle, and thence across subopercle: a short faint one across cheek to preopercular ridge, and one running backward from end of maxillary. Spinous dorsal reddish brown, with large, blended, transparent spots. Anal and caudal uniform reddish brown; pectoral yellowish and transparent; ventral orange, black at tip, its inner ray white.

This species is known from San Francisco to Todos Santos Bay, Lower California (Jordan and McGregor, 1898, p. 278).

Family LUTIANIDÆ.

88. **Xenistius californiensis** (Steindachner).

(Jordan and Evermann, 1898, II, p. 1286.)

Reported to be sometimes abundant about San Diego; not seen by us. Known southward to Guaymas in the Gulf of California (Evermann and Jenkins, 1891, p. 144).

Family HÆMULIDÆ.

89. **Anisotremus davidsoni** (Steindachner).

SARGO RAIADO.

(Jordan and Evermann, 1898, II, p. 1321.)

Reported to be not rare about San Diego in the summer time (Eigenmann, 1892, p. 152): not seen by us. It is known to range from San Pedro (Jordan and Gilbert, 1880, p. 456) to San Bartolome Bay, Lower California.

Family GERRIDÆ.

90. **Eucinostomus californiensis** (Gill).

(Jordan and Evermann, 1898, II, p. 1369.)

Once taken at San Diego by Dr. Eigenmann (1892, p. 154); known southward to Guayaquil, Ecuador (Starks, 1906, p. 792).

Family KYPHOSIDÆ.

91. **Medialuna californiensis** (Steindachner).

MEDIALUNA.

(Jordan and Evermann, 1898, II, p. 1391, fig. 560.)

Common on the coast of Southern California about rocky places; one specimen taken at La Jolla. Not seen in San Diego Bay. Known from Santa Barbara (Jordan and Gilbert, 1880, p. 456) south to Cerros Island (Jordan and McGregor, 1898, p. 279).

92. **Girella nigricans** (Ayres).

GREEN FISH.

(Jordan and Evermann, 1898, II, p. 1382.)

The young up to ten inches in length are very abundant in the tide pools.

Color in life olive green with bright blue borders to the fins and membrane following the gill opening. The blue follows the edge of the dorsal across the tips of the spines and rays, but follows the rays longitudinally on the upper and lower edges of the caudal and on the front of the anal. The ventrals are tipped with blue; the pectorals are yellowish. There is a very conspicuous light spot on the back below the middle of the base of the dorsal. It is not at all constant in position, one being frequently behind the other on opposite sides of the same fish. Sometimes there are two spots on each side, and occasionally two on one side and one on the other. When the fish has been dead a short time the blue color on the fins entirely disappears, and the spot on the side is not very conspicuous.

Known from San Francisco south to Guaymas, Mexico (Evermann and Jenkins, 1891, p. 154).

Family SCIAENIDÆ.

93. **Cyanoscion nobilis** (Ayres).

WHITE SEA BASS.

(Jordan and Evermann, 1898, II, p. 1413.)

An important food fish. Many specimens seen at Santa Barbara, and an occasional one from off Point Loma. It is known

from Victoria (Jordan and Evermann, *l. c.*) south to the Gulf of California, where it was taken by the U. S. S. Albatross (Station 3026); probably rare north of San Francisco.

94. **Cynoscion parvipinnis** Ayres.

(Jordan and Evermann, 1898, II, p. 1410.)

Reported to be sometimes common on the Southern California coast. A specimen seen from San Diego. It is known from San Pedro (Jordan and Gilbert, 1880, p. 456) south to Guaymas, Mexico (Evermann and Jenkins, 1891, p. 159).

95. **Seriphus politus** Ayres.

QUEENFISH; WHITE CROAKER.

(Jordan and Evermann, 1898, II, p. 1397.)

Common in San Diego Bay. Known northward to San Francisco (Jordan and Gilbert, 1880, p. 456).

96. **Sciaena saturna** (Girard).

BLACK CROAKER.

(Jordan and Evermann, 1898, II, p. 456.)

One specimen 12½ inches long from San Diego Bay. There are 70 scales in the lateral line (55 to 60 in current descriptions). We may here call attention to a mistake in the description of this species by Jordan and Evermann. The caudal in the beginning of the description is said to be lunate, as it is in our specimen, but further on in the same description it is again described as "caudal fin slightly convex, its middle rays longest."

This species is known from Santa Barbara (Jordan and Gilbert, 1880, p. 456) south to the Gulf of California (Albatross Station 3026, Gilbert, MS. notes).

97. **Roncador stearnsi** (Steindachner).

RANCADOR.

(Jordan and Evermann, 1898, II, p. 1457, fig. 568.)

This species was taken in abundance in San Diego Bay during the latter part of July, though it was not seen before that time. It may at once be known by a conspicuous black spot at the base

of the pectoral. Known northward to San Francisco, where a specimen was collected in the market by Dr. Jordan. It has not before been recorded north of Santa Barbara.

98. **Genyonemus lineatus** (Ayres).

KINGFISH.

(Jordan and Evermann, 1898, II, p. 1460.)

Several specimens were taken at San Pedro. The young from one and one-half to three inches in length differ from the adults in having a rather strong spine at the angle of the preopercle, with a weaker one above and below. The oblique dark stripes are absent, but there are about twelve wide, dark, vertical bars on side of body and head, which often extend on to the back.

It is known from San Francisco southward to Todos Santos Bay (Jordan and McGregor, 1898, p. 279).

99. **Umbrina roncador** Jordan and Gilbert.

YELLOW-TAILED CROAKER.

(Jordan and Evermann, 1898, II, p. 1467.)

This species was very common about San Diego Bay in July and August, though it was not seen early in the year. Known south to Pesqueña Bay, Lower California (the type locality), and north to San Francisco. Here recorded from the latter locality for the first time from a specimen collected in the market by Dr. Jordan.

100. **Menticirrhus undulatus** (Girard).

CALIFORNIA WHITING.

(Jordan and Evermann, 1898, II, p. 1476, fig. 570.)

A specimen 16 inches in length, taken in San Diego Bay, differs from current descriptions in the following proportions: Head 4⅖ in body to base of caudal; depth 5. Eye 8 in head, 3 in snout, 2 in interorbital space. Highest dorsal spine 1⅗ in head. Tips of dorsal spines when reclined reach to dorsal rays.

Known southward to the head of the Gulf of California (Gilbert, MS. notes) and northward to Santa Barbara (Jordan and Gilbert, 1880, p. 456).

Family EMBIOTOCIDÆ.

101. **Abeona minima** (Gibbons).

(Jordan and Evermann, 1898, II, p. 1497, fig. 578.)

Numerous specimens taken on Point Loma and at La Jolla in tide pools. Known from San Francisco (Jordan and Gilbert, 1880, p. 456) southward to Todos Santos Bay (Jordan and McGregor, 1898, p. 281). It has also been taken from San Nicholas, Santa Cruz, and San Martin Islands (Gilbert, MS. notes). It is the smallest member of the family, and is not uncommon.

102. **Cymatogaster aggregatus** Gibbons.

VIVIPAROUS PERCH.

(Jordan and Evermann, 1898, p. 1498, figs. 579, 579*a*.)

This is the most abundant surf-fish in San Diego Bay, a haul of the seine seldom failing to bring in some of them. This species is known northward to Fort Wrangle, Alaska (Bean, 1884, p. 361). It is the northernmost species of the family. It is everywhere abundant south of Puget Sound.

103. **Brachyistius frenatus** Gill.

(Jordan and Evermann, 1898, II, p. 1499, fig. 580.)

Apparently rare on the Southern California coast; not seen by us. Known from Puget Sound (Jordan and Starks, 1895, p. 797) southward to Guadalupe Island, Lower California (Jordan and McGregor, 1897, p. 281).

104. **Zalembius rosaceus** (Jordan and Gilbert).

(Jordan and Evermann, 1898, II, p. 1500.)

Specimens taken off San Diego and other points off Southern California (Gilbert, MS. notes) extend the range of this species southward. It is found north to San Francisco (type locality).

105. **Hyperprosopon argenteus** Gibbons.

WALL-EYED SURF-FISH.

(Jordan and Evermann, 1898, II, p. 1501.)

Not uncommon in San Diego Bay. Known northward to Astoria, Oregon (Girard, 1858, p. 197). Usually common on sandy beaches.

106. **Hyperprosopon agassizii** Gill.

(Jordan and Evermann, 1898, II, p. 1502.)

Reported southward to Santa Barbara; not seen by us. Known from San Francisco to Santa Barbara (Jordan and Gilbert, 1880, p. 456). Rather common southward.

107. **Holconotus rhodoterus** Agassiz.

(Jordan and Evermann, 1898, II, p. 1502.)

Rather rare; not seen by us. It ranges from San Francisco (Jordan and Gilbert, 1880, p. 456) to San Diego (Eigenmann, 1892, p. 156).

108. **Amphistichus argenteus** Agassiz.

SURF-FISH.

(Jordan and Evermann, 1898, II, p. 1503.)

Reported by Eigenmann (1892, p. 156) to be common in the surf of the ocean beaches, but not taken in San Diego Bay. A specimen examined from San Clemente Island. Known northward to Cape Flattery (Girard, 1858, p. 199).

109. **Embiotoca jacksoni** Agassiz.

BLACK PERCH.

(Jordan and Evermann, 1898, II, p. 1504.)

Next to *Cymatogaster aggregatus*, the most abundant surf-fish in San Diego Bay. The largest specimen taken was thirteen inches in length. During the latter part of December and the early part of January females were with young apparently ready to be born. The young were forty-three millimeters in entire length, the tail being a third of this, and the other fins were about as long.

Adult life color: Olive green or occasionally reddish brown, lighter on side than on back or belly; each scale with a bright cobalt blue spot, especially in smaller specimens; several faint dusky bars on back and side. Vertical fins dark blue, the anal bright cobalt at base. Occasional specimens have the ventrals

dark blue at base, but changing abruptly to bright orange, and at irregular intervals a single anal ray is bright orange.

This species occurs from Puget Sound (Jordan and Starks, 1895, p. 797) south to Cerros Island (Jordan and McGregor, 1898, p. 281.) It is not abundant northward.

110. **Taeniotoca lateralis** (Agassiz).

STRIPED SURF-FISH.

(Jordan and Evermann, 1898, II, p. 1505.)

Rare southward; not seen by us. It is found from San Benito Island, Lower California (Jordan and McGregor, 1898, p. 281) northward to Puget Sound (Jordan and Starks, 1895, p. 797).

111. **Phanerodon furcatus** Girard.

WHITE SURF-FISH.

(Jordan and Evermann, 1898, II, p. 1506, fig. 583.)

Several specimens taken at San Diego Bay. Found north to San Francisco (Jordan and Gilbert, 1880, p. 456) in abundance.

112. **Phanerodon atripes** (Jordan and Gilbert).

(Jordan and Evermann, 1898, II, p. 1507.)

One specimen taken in San Diego Bay. Occurring from Monterey Bay (Jordan and Gilbert, 1880, p. 456) to San Diego; abundant northward.

113. **Rhocochilus toxotes** Agassiz.

ALFIONE.

(Jordan and Evermann, 1898, II, p. 1507, fig. 584.)

One specimen from San Pedro. Ranging from San Francisco (Jordan and Gilbert, 1880, p. 456) to San Diego (Eigenmann, 1892, p. 157). It is rather common northward, but rare at San Diego.

114. **Hypsurus caryi** (Agassiz).

(Jordan and Evermann, 1898, II, p. 1508, fig. 585.)

Rare south of Point Conception; not seen by us. Known from San Francisco (Jordan and Gilbert, 1880, p. 456) to San Diego (Smith, 1880); common northward.

115. **Damalichthys argyrosomus** (Girard).

WHITE PERCH.

(Jordan and Evermann, 1898, II, p. 1509, fig. 586.)

Reported by Eigenmann (1892, p. 157) to be moderately abundant at San Diego in the winter time. Not seen by us. It is found northward to Puget Sound (Jordan and Starks, 1895, p. 797).

Family POMACENTRIDÆ.

116. **Chromis punctipinnis** (Cooper).

BLACKSMITH.

(Jordan and Evermann, 1898, II, p. 1548.)

Not uncommon south of Point Conception; specimens examined in the collection of the San Diego Natural History Society. Known from Cerros Island (Jordan and McGregor, 1898, p. 282) to Santa Barbara (Jordan and Gilbert, 1880, p. 455). It is rather common about rocky places.

117. **Hypsypops rubicunda** (Girard).

GARABALDI; GOLDFISH.

(Jordan and Evermann, 1898, II, p. 1564, fig. 591.)

Specimens from La Jolla and San Pedro; very abundant in rocky places at the former locality. It is known southward to Cerros Island (Jordan and McGregor, 1898, p. 282) northward to Santa Barbara (Jordan and Gilbert, 1880, p. 455). It is also known from the Santa Barbara Islands.

Family LABRIDÆ.

118. **Pimelometopon pulcher** (Ayres).

FAT-HEAD; REDFISH.

(Jordan and Evermann, 1898, II, p. 1585, fig. 598.)

Very common at San Diego outside of the bay. Known southward to Guadalupe Island (Jordan and McGregor, 1898, p. 283), and northward to Monterey (Jordan and Gilbert, 1880, p. 455). It reaches a weight of fifteen pounds, and is caught in great abundance on the Southern California coast.

119. **Halichoeres semicinctus** (Ayres).

KELPFISH.

(*Iridio semicinctus* Jordan and Evermann, 1898, II, p. 1592.)

Specimens from the ocean-side of Point Loma. It occurs from San Pedro (Jordan and Gilbert, 1880, p. 455) southward to Cerros Island (the type locality). It is a common species and reaches a length of a foot.

120. **Oxyjulis californica** (Günther).

SENORITA.

(Jordan and Evermann, 1898, II, p. 1601.)

Several specimens from La Jolla; the young rather common in the tide pools. Ranging from Guadalupe Island (Jordan and McGregor, 1898, p. 283) northward to Monterey Bay (Jordan and Gilbert, 1880, p. 455).

Family EPHIPPIDÆ.

121. **Chaetodipterus zonatus** (Girard).

ANGEL-FISH.

(Jordan and Evermann, 1898, II, p. 1668.)

The type of this species was taken at San Diego by Girard (1858, p. 110), but has not since been taken so far north. It is abundant from Mazatlan to Guayaquil, Ecuador.

Family BALISTIDÆ.

122. **Balistes cinereus** Richardson.

PEZ PUERCO.

(*Balistes polylepis* Jordan and Evermann, 1898, II, p. 1700.)

A stuffed skin of this species that was taken by Mr. T. Shooter at Santa Catalina Island was sent to Dr. Jordan, and Dr. Jordan recently saw a live specimen in the aquarium at that locality. It has not before been recorded north of Magdalena Bay, Lower California. It ranges south to Panama.

Family TETRAODONTIDÆ.

123. **Spheroides politus** (Girard).

(*Spheroides annulatus politus* Jordan and Evermann, 1898, II, p. 1736.)

This species was recorded from San Diego by Girard (1858, p. 340), but has not since been seen so far north. It is known southward to Mazatlan, Mexico.

Family DIODONTIDÆ.

124. **Chilomycterus affinis** Günther.

(*Chilomycterus californiensis* Jordan and Evermann, 1898, II, p. 1751.)

This species is known from Japan, the Hawaiian, and the Galapagos Islands. We follow Jordan and Evermann (1903, p. 438) in referring *Chilomycterus californiensis* Eigenmann from San Pedro to this species, though it appears to differ somewhat in color. Eigenmann's type is the only specimen known from our coast.

Family MOLIDÆ.

125. **Mola mola** (Linnæus).

SUNFISH; MOLA.

(Jordan and Evermann, 1898, II, p. 1753, fig. 651.)

Occasionally taken by the fishermen; a stuffed skin seen at San Diego. This is a pelagic species, inhabiting most temperate and tropical seas, and is found as far north as England, Cape Cod, and San Francisco. It is said to reach a weight of 1,500 pounds, but is of no value.

126. **Sebastolobus alascanus** Bean.

(Jordan and Evermann, 1898, II, p. 1761.)

Known from deep water from Alaska to Santa Barbara Island, where specimens were taken on trawl lines in from ten to fifteen fathoms of water (Gilbert, 1898, p. 25).

Family SCORPÆNIDÆ.

127. **Sebastolobus altivelis** Gilbert.

(Jordan and Evermann, 1898, II, p. 1763, fig. 654.)

Specimens have been taken in rather deep water off San Diego. Its range extends northward to Alaska. It reaches a length of a little more than a foot, and is occasionally taken by fishermen on long lines when fishing for *Sebastodes*.

128. **Sebastodes goodei** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1779.)

One specimen 15 inches in length taken in deep water off Point Loma. It has a series of transverse, dark bars below the lateral line, slightly arched toward the head. Specimens in the Stanford University collections show some variations from the original description (Eigenmann and Eigenmann, 1890, p. 12). Specimens from 8½ to 18 inches long have the eye from 3⅚ to 4⅗ in head, slightly shorter than length of snout. In a specimen 5 inches long the eye is 3⅓ in head and longer than snout. In specimens from 12 to 18 inches long the diameter of the eye is less than the interorbital width; in specimens from 5 to 8½ inches long the eye is greater than the interorbital width. The interorbital width is contained from 3¾ to 4½ in head. In specimens from 8½ to 18 inches long the occipital ridges do not end in spines; in specimens 5 inches long they do end in spines. In specimens from 15 to 18 inches long the depth of the caudal peduncle is a little greater than the diameter of the orbit; in a specimen 12 inches long it is equal to the diameter of the orbit; and in smaller specimens it is less than the diameter of the orbit. The second anal spine is from ½ to ⅔ of the diameter of the orbit in all of these specimens.

This species is taken in abundance about the Santa Barbara Islands, Coronado Islands, and Cortez Banks in rather deep water. It reaches a length of 18 inches, and extends its range northward to Monterey (Gilbert, 1893, p. 466).

129. **Sebastodes paucispinis** (Ayres).

BOCACCIO.

(Jordan and Evermann, 1898, II, p. 1780.)

Abundant in rather deep water off San Diego, and ranging northward to San Francisco (the type locality). It is one of the most important of the rockfish, reaching a weight of 15 pounds. The young are found in shallow water northward, and are caught with hook and line by the boys, who know them as "Tom-cod." We did not see the young in San Diego Bay.

130. **Sebastodes flavidus** (Ayres).

YELLOW-TAIL ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1781.)

A few specimens seen in the San Diego market. It is found in abundance northward to San Francisco (type locality), and reaches a length of two feet, though its usual length is about 16 inches. Its yellow tail will usually serve to distinguish it from other species.

131. **Sebastodes serranoides** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1782.)

Not uncommon in deep water off San Diego. Its northern range is unknown. Cortez Banks is the type locality.

132. **Sebastodes mystinus** Jordan and Gilbert.

BLACK ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1784, fig. 627.)

Specimens seen in the San Diego markets. It ranges northward to Puget Sound (Jordan and Gilbert, 1880, p. 455), and is very abundant about San Francisco. It is an important food fish and reaches a weight of five pounds.

133. **Sebastodes rufus** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1786.)

Originally described from off Point Loma and Cortez Banks. Not seen by us. It reaches a length of 22 inches.

134. **Sebastodes macdonaldi** (Eigenmann and Beeson).

(Jordan and Evermann, 1898, II, p. 1786.)

Described off San Diego; length 24 inches; not seen by us.

135. **Sebastodes ovalis** (Ayres).

(Jordan and Evermann, 1898, II, p. 1788.)

Reported to be rather common by Eigenmann (1892, p. 163), in the San Diego markets; not seen by us. It ranges northward to San Francisco, and is not very important as a food fish.

136. **Sebastodes alutus** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1790, fig. 661.)

The type of this species was taken by the U. S. S. Albatross near Santa Cruz Island. It has not since been taken on the California coast, but it is abundant about the Aleutian Islands (Gilbert, 1893, p. 408).

137. **Sebastodes proriger** (Jordan and Gilbert).

(Jordan and Evermann, 1898, II, p. 1792.)

This species is rather abundant in deep water off San Diego. Said by Eigenmann (1892, p. 164) to reach a length of two feet. It is not usually found, however, to exceed a foot in length. It ranges northward to San Francisco (Jordan and Gilbert, 1880, p. 455).

138. **Sebastodes pinniger** (Gill).

ORANGE ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1793, fig. 662.)

Not very abundant southward; one specimen seen in the market at San Diego. It ranges north to Puget Sound (Jordan and Gilbert, 1880, p. 455), and about San Francisco; is one of the most abundant and important of the rockfishes.

139. **Sebastodes miniatus** (Jordan and Gilbert).

RASCIERA.

(Jordan and Evermann, 1898, II, p. 1794.)

This is a large and important fish at San Diego; it is represented in every boat load of rockfishes that is brought in. The

deep vermillion color of the back, dusted over with black dots, is different from any other of the red rockfishes. It is found northward to San Francisco (Jordan and Gilbert, 1880, p. 455).

140. **Sebastodes atrovirens** (Jordan and Gilbert).

GARRUPA.

(Jordan and Evermann, 1898, II, p. 1797.)

This species is said to be common on the Southern California coast; it was not seen by us. It is found from San Diego (Eigenmann, 1892, p. 164) to San Francisco (Jordan and Gilbert, 1880, p. 455), and reaches a length of 15 inches.

141. **Sebastodes saxicola** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1798.)

Specimens taken from near San Pedro. The typical specimens were taken in abundance about the Santa Barbara Islands from 44 to 155 fathoms by the U. S. S. Albatross. It is found northward to the coast of Oregon (Gilbert, MS. notes).

142. **Sebastodes semicinctus** Gilbert.

(Jordan and Evermann, 1898, II, p. 1800.)

This is a small species, only 7 inches in length, known from deep water in the Santa Barbara Channel. The typical specimens were taken in 55 and 155 fathoms.

143. **Sebastodes diploproa** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1801.)

A small species taken by the U. S. S. Albatross in 124 fathoms about the Coronado Islands. It is known northward to San Francisco (Gilbert, 1893, p. 467).

144. **Sebastodes aurora** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1802.)

The typical specimens taken by the U. S. S. Albatross about the Santa Barbara Islands, in 233 and 267 fathoms, 12 inches in length. It is known northward to Monterey Bay (Gilbert, 1893, p. 467).

145. **Sebastodes melanostomus** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1803.)

Known only from the type, about 22 inches in length, from off Point Loma; probably rare.

146. **Sebastodes introniger** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1803.)

This species was described from two specimens taken by the U. S. S. Albatross about the Santa Barbara Islands in 266 fathoms, and has since been taken by the Albatross near Unalaska Island in depths of from 85 to 350 fathoms.

147. **Sebastodes ruberrimus** Cramer.

RED ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1805.)

This is one of the largest of the rockfishes, reaching a length of 30 inches. It is found from Puget Sound (Jordan and Gilbert, 1880, p. 455) to San Diego. Eigenmann (1892, p. 164) records it from the latter locality under the name *Sebastodes ruber*.

148. **Sebastodes constellatus** (Jordan and Gilbert).

SPOTTED ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1806.)

Specimens seen in the San Diego markets on several occasions. It ranges north to San Francisco (Jordan and Gilbert, 1880, p. 455), and is generally common. It is a well-marked species and may be known by the color: bright red with shades of orange, olive on the back, everywhere covered with small flakes of white or light rose color.

149. **Sebastodes umbrosus** (Jordan and Gilbert).

(Jordan and Evermann, 1898, II, p. 1807.)

One specimen taken in deep water off Point Loma. This is apparently a rare species, and is confined to the coast of California below Point Conception.

150. **Sebastodes rosaceus** (Girard)

CORSAIR.

(Jordan and Evermann, 1898, II, p. 1808.)

This is a small bright red rockfish abundant from San Francisco to San Diego; specimens often seen in the market at the latter place. It is known southward to Cerros Island (Gilbert, MS. notes).

151. **Sebastodes ayresii** Gilbert and Cramer.

(Jordan and Evermann, 1898, II, p. 1808.)

Known only from the type, 9 inches in length, taken on a trawl line at Cortez Banks by the U. S. S. Albatross.

152. **Sebastodes rhodochloris** (Jordan and Gilbert).

FLY FISH.

(Jordan and Evermann, 1898, II, p. 1809.)

One specimen, 11½ inches in length, taken off Point Loma. It agrees in most respects with the original description. The narrowest width of the interorbital space is equal to the length of the supraocular spine; the longest dorsal spine is contained 3 times in the head; the second anal spine is shorter than the maxillary or the base of the soft dorsal, and is contained 2½ times in the head. In the original description the width of the interorbital space is said to be less than the length of the supraocular spine; the longest dorsal spine is contained 2⅔ times in the head; and the second anal spine is equal to the length of the maxillary, or the base of the soft dorsal, or 1½ of the head.

A specimen 6 inches in length (locality unknown) agrees in all of the above respects with the original description.

This species is rather rare and has hitherto been recorded only from deep water off Monterey (type locality), and from off Point Conception. (Albatross Station 2973, Gilbert, MS. notes.)

153. **Sebastodes eos** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1810.)

Known only from off Point Loma, where it is reported by Eigenmann (1892, p. 165) to be abundant at times. Not seen by us.

154. **Sebastodes gilli** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1811.)

This species is known only from the typical specimens taken off Point Loma.

155. **Sebastodes chlorostictus** (Jordan and Gilbert).

PESCA VERMIGLIA.

(Jordan and Evermann, 1898, II, p. 1811.)

One specimen from near San Pedro. It is found in abundance in deep water northward to San Francisco, and reaches a length of 15 inches. It is a very pretty fish; light red or pink on sides with shades of orange; upper part of body closely covered with small round green spots.

156. **Sebastodes rupestris** Gilbert.

(Jordan and Evermann, 1898, II, p. 1812.)

This species is known from the typical specimens from the Santa Barbara Islands, and from a specimen from off Cerros Island (Gilbert, MS. notes.)

157. **Sebastodes zacentrus** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1814.)

This species is known from the Santa Barbara Islands (type locality) to Coos Bay, Oregon. A specimen in the Stanford University collections from the latter locality.

158. **Sebastodes elongatus** (Ayres).

REINA.

(Jordan and Evermann, 1898, II, p. 1815.)

Specimens from San Pedro. A small well-marked species found in abundance in rather deep water from San Diego (Eigenmann, 1892, p. 165) to a little north of Point Reyes (Gilbert, 1893, p. 408).

159. **Sebastodes levis** (Eigenmann and Eigenmann).

COWFISH.

(Jordan and Evermann, 1898, II, p. 1816).

Daily brought to the San Diego market. It is locally known as the cowfish, a name without obvious application unless on account of its size. It reaches a length of three feet and a weight of 30 pounds.

160. **Sebastodes rubrivinctus** (Jordan and Gilbert).

SPANISH FLAG.

(Jordan and Evermann, 1898, II, p. 1817.)

Reported by Eigenmann (1892, p. 166) to be occasionally brought to the San Diego markets. With its broad cross-bands of red, white and red it is appropriately known as the Spanish flag. In coloration it is the most brilliant fish on our coast. It is a rather rare species found in deep water northward to San Francisco.

161. **Sebastodes auriculatus** (Girard).

BROWN ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1817.)

A specimen from San Pedro. This is a small rockfish found from San Martin Island (Jordan and Gilbert, 1881*a*, p 279) northward to San Francisco. North of Point Conception it is found in the shallow bays, but at San Diego in common with many other species of similar habits it is unknown from the bay, probably on account of the warm water. It may readily be known by the presence of coronal spines (see Cramer, 1895, Pl. LXV, fig. 26).

162. **Sebastodes rastrelliger** (Jordan and Gilbert).

GRASS ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1819.)

This species is known from San Diego (Eigenmann, 1892, p. 167) to San Francisco (Jordan and Gilbert, 1880, p. 455). It is

abundant in water of moderate depths, especially south of Point Conception, and reaches a length of 15 inches. From its relatives it may be at once known by its very short gill rakers. General color dusky green with paler mottlings.

163. **Sebastodes vexillaris** (Jordan and Gilbert).

(Jordan and Evermann, 1898, II, p. 1821.)

One specimen from off Point Loma. This is one of the larger rockfishes, reaching a length of two feet. It is found in great abundance from San Diego to San Francisco (Jordan and Gilbert, 1880, p. 455).

164. **Sebastodes gilberti** Cramer.

(Jordan and Evermann, 1898, II, p. 1823.)

Specimens from San Pedro. This is a rare species hitherto known only from about San Francisco (type locality), and now recorded for the first time from Southern California.

165. **Sebastodes carnatus** (Jordan and Gilbert).

FLESH-COLORED ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1824.)

Several specimens taken off Point Loma, and the young up to four inches long taken in tide pools on the ocean side of the point. It was the only species of rockfish we found in the pools. They are darker than specimens from Monterey Bay; the flesh-colored blotches are less distinct, especially on the large fish. This species reaches a length of 15 inches, and is found in rather shallow water north to San Francisco (Jordan and Gilbert, 1880, p. 455).

166. **Sebastodes chrysomelas** (Jordan and Gilbert).

BLACK AND YELLOW ROCKFISH.

(Jordan and Evermann, 1898, II, p. 1825.)

This is one of the smaller of the rockfishes, and is found in water of moderate depths from San Diego (Eigenmann, 1892, p. 167) to San Francisco. It is abundant in shallow water about San Diego, but does not enter the bay. It is well marked in color

and can be readily distinguished by that character alone. Black or very dark brown with blotches of clear, warm, brownish yellow in more or less definite areas. The dark color predominating above, the yellow below.

167. **Sebastodes serriceps** (Jordan and Gilbert).

TREEFISH.

(Jordan and Evermann, 1898, II, p. 1827, fig. 667.)

A small specimen taken at San Pedro. This is a moderate sized rockfish found in rather shallow water from San Diego (Eigenmann, 1892, p. 168) to San Francisco. It is strikingly marked with about seven black cross-bands on a ground of yellow shading to coppery red.

168. **Scorpaena guttata** Girard.

SCULPIN; SCORPENE.

(Jordan and Evermann, 1898, II, p. 1847.)

Rather common in San Diego Bay. Young specimens have a broad, light cross-band, its width equal to length of maxillary, extending across middle of body and involving posterior ⅔ of spinous dorsal, front of soft dorsal, tips of pectoral and ventral, and anterior edge of anal. Another similar but somewhat narrower band across the posterior part of the body and posterior half of dorsal and anal. A third band on basal ⅔ of caudal fin, and a light border on caudal fin posteriorly. A specimen in the collection of the Marine Biological Association's laboratory at La Jolla has 13 spines in the dorsal.

Found from Ascension Island on the west coast of Mexico (Jordan and Gilbert, 1881*a*, p. 278) northward to Monterey (the type locality). It reaches a length of a foot and is a food fish of fair quality. The wound made by the dorsal spines of this fish is said to be exceedingly painful, like the sting of a sting-ray. From this fact it doubtless has received its common name Scorpene—Scorpion.

Family ANOPLOPOMATIDÆ.

169. **Anoplopoma fimbria** (Pallas).

COALFISH; BLACK COD.

(Jordan and Evermann, 1898, II, p. 1862, fig. 675.)

This species is here recorded on our southern coast for the first time. One specimen was seen from the deep water off Point Loma, where it is reported by the fishermen to be not uncommon. It is sometimes salted, but there is no market for it in the fresh state, being dry and tasteless. It ranges northward to Sitka (Bean, 1881, p. 254) in moderately deep water, and is abundant in Puget Sound.

Family HEXAGRAMMIDÆ.

170. **Ophiodon elongatus** Girard.

BLUE COD.

(Jordan and Evermann, 1898, II, p. 1875, fig. 682.)

One specimen seen in the San Diego market. The fishermen report it to be not rare in the deeper waters off Point Loma. Its range extends northward to Sitka, Alaska (Bean, 1881, p. 254), and in northern waters it reaches a length of five feet and a weight of sixty pounds. North of Conception Point it is very abundant and is one of the most important fishes of our coast. Its common names "Blue Cod," "Cultus Cod," "Bastard Cod," and "Buffalo Cod" are all unfortunate, as it is unrelated to the true codfish.

171. **Zaniolepis latipinnis** Girard.

(Jordan and Evermann, 1898, II, p. 1876.)

Several small specimens, the largest 2½ inches in length, taken at San Pedro.

In the key to the species of *Zaniolepis*, Jordan and Evermann state that no supraorbital flap is present in this species. An examination of many specimens in the Stanford University collections from different localities shows the supraorbital flap present about as often as absent; occasionally present on one side only.

It is much smaller than in *Zaniolepis frenatus,* and often difficult to find.

This species ranges northward to Puget Sound (the type locality) to San Diego (Gilbert, MS. notes). It may be easily known from *Zaniolepis frenatus* by the long second spine of the dorsal which is always longer than the head, and in large specimens half as long as the entire body. It reaches a length of 12 inches.

172. **Zaniolepis frenatus** Eigenmann.

(Jordan and Evermann, 1898, II, p. 1877.)

This species is known from the Santa Barbara Islands (Gilbert, 1898, p. 26), and from Cortez Banks (the type locality). It does not exceed eight inches in length.

173. **Oxylebius pictus** Gill.

(Jordan and Evermann, 1898, II, p. 1878.)

A specimen recorded by Dr. Gilbert (MS. notes) from off San Miguel Island increases the range of this species southward from Monterey. It is known northward to Puget Sound (Jordan and Starks, 1895, p. 802).

Family COTTIDÆ.

174. **Paricelinus hopliticus** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1886.)

Hitherto known only from a single small specimen from the stomach of *Sebastodes levis* taken at a depth of 48 fathoms on Cortez Banks. Dr. Gilbert (MS. notes) records a specimen (''partly digested'') from off Oregon.

175. **Scorpaenichthys marmoratus** (Ayres).

CABEZON.

(Jordan and Evermann, 1898, II, p. 1889.)

Reported to be not rare near San Diego; one specimen seen. It is the largest sculpin on the Pacific Coast, and ranges northward to Puget Sound (Jordan and Starks, 1895, p. 808), being most abundant about Monterey. Its value is small, as its flesh is tough and of poor flavor.

176. **Chitonotus pugetensis** (Steindachner).

(Jordan and Evermann, 1898, II, p. 1890, fig. 687.)

Specimens from San Pedro. A specimen in the Stanford University collections taken by the U. S. S. Albatross near San Diego extends the range of this species southward. It grows to a length of six inches, and ranges north to Puget Sound (the type locality), being not rare in water of moderate depth. A specimen 1¼ inches in length has the upper preopercular spine bifid with no trace of additional prongs. The adults agree with the description by Jordan and Evermann in this as in other characters.

177. **Tarandichthys cavifrons** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1891.)

One specimen from San Pedro. It is known only from about the Santa Barbara Islands in rather deep water. Length 3½ inches. It may be known from other species of *Tarandichthys* by a pit-like depression at the occiput.

178. **Tarandichthys filamentosus** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1892.)

Coast of Southern California in rather deep water; no specimens seen by us. It reaches a length of 9 inches. It may be known from *Tarandichthys tenuis* by the first two dorsal spines being produced into long filaments which reach to the middle of the soft dorsal.

179. **Tarandichthys tenuis** (Gilbert).

(Jordan and Evermann, 1898, II, p. 1893.)

Several specimens from San Pedro. This species is known only from the vicinity of the Santa Barbara Islands in rather deep water. The second dorsal spine is sometimes slightly produced, but is never long.

180. **Icelinus fimbriatus** Gilbert.

(Jordan and Evermann, 1898, II, p. 1895.)

Known from specimens taken by the U. S. S. Albatross in rather deep water off the Santa Barbara Islands. It may be

easily known from *Icelinus quadriseriatus,* the only other *Icelinus* found in this region, by the tentacles on the nasal spines.

181. **Icelinus quadriseriatus** (Lockington).

(Jordan and Evermann, 1898, II, p. 1897.)

Specimens taken in abundance on the banks off Point Loma, and near San Pedro. They have from 8 to 10 spines, and 13 or 14 rays in the dorsal. The pectoral reaches a little past the front of anal. A black spot is present at each end of spinous dorsal, and a bright canary yellow spot is on lower part of the mandible in life. This species is abundant in waters of moderate depths north of San Francisco (the type locality).

182. **Astrolytes notospilotus** (Girard).

(Jordan and Evermann, 1898, II, p. 1899, fig. 689.)

Abundant off Santa Barbara (Jordan and Gilbert, 1880, p. 61); no specimens seen by us. It reaches a length of 10 inches, and is found north to Puget Sound (Jordan and Gilbert, 1881, p. 454).

183. **Icelus australis** Eigenmann and Eigenmann.

(Jordan and Evermann, 1898, II, p. 1918.)

Known only from two small partly digested specimens from the stomach of *Sebastodes miniatus* taken at Cortez Banks.

184. **Rudulinus boleoides** Gilbert.

(Jordan and Evermann, 1898, II, p. 1919.)

Known only from the type taken off Santa Catalina Island by the U. S. S. Albatross.

185. **Calycilepidotus spinosus** Ayres.

(Jordan and Evermann, 1898, II, p. 1937.)

Hitherto known only from Monterey and San Francisco in rather deep water. Here recorded (Gilbert, MS. notes) from off the Santa Barbara Islands.

186. **Enophrys bison** (Girard).

(Jordan and Evermann, 1898, II, p. 1938.)

A specimen in Stanford University taken a little south of Point Conception extends the range of this species southward from San Francisco. It is known northward to Sitka, Alaska (Bean, 1881, p. 249).

187. **Leiocottus hirundo** Girard.

(Jordan and Evermann, 1898, II, p. 2011, fig. 732.)

This species reaches a length of 10 inches, and is known only from the Santa Barbara Islands. It is abundant but extremely local. Not seen by us.

188. **Leptocottus armatus** Girard.

(Jordan and Evermann, 1898, II, p. 2012.)

Very common in San Diego Bay; a haul of the seine seldom failed to bring in several small ones. The largest taken was 6½ inches in length. Our specimens agree with the original description and with current descriptions only when measured in total length to tip of caudal. Head 2⅘ in length to base of caudal; depth 5½. The eye is greater than the interocular width, and is contained 6⅔ times in head in our largest specimens (not less than interocular width, 7½ times in head).

This species is one of the most abundant Cottoids on the Pacific Coast, and is known from Kadiak Island, Alaska (Bean, 1881, p. 251), to San Diego. It is found in shallow water, and reaches a length of a foot.

189. **Clinocottus analis** (Girard).

(Jordan and Evermann, 1898, II, p. 2012.)

One of the commonest fishes in the rock pools; not seen inside of San Diego Bay. The large males often develop conspicuous flaps on the tips of the anterior dorsal spines.

In life: slate color with 5 or 6 irregular black cross bars, these very conspicuous in the water but much less so when the fish is

dead. Sometimes, especially in large specimens, everywhere spotted with orange dots. Belly and chin light drab or green in small specimens, the latter spotted with darker; sides of head coal black. Pectoral with red shades; membrane of soft dorsal sometimes edged with brilliant red. A dark band on caudal usually black, sometimes red; membrane of caudal light reddish, and with transparent spots. Some specimens taken in clear, open pools with sandy bottoms were very light, but when dead could not be distinguished from the others.

This species occurs from San Francisco southward to San Martin Island, Lower California (Jordan and McGregor, 1898, p. 284). It reaches a length of 7 inches, and is everywhere abundant in tide pools. It may be readily known from other Cottoids occurring with it by the rough feeling when the finger is passed along the side toward the head.

190. **Oligocottus rubellio** (Greeley).

(*Eximia rubellio*, Jordan and Evermann, 1900, IV, p. 3182.)

Four specimens taken in the tide pools on the ocean side of Point Loma. The species may be known from *Oligocottus maculosus* by its longer head and larger eye.

Color in life: body light translucent green with black cross spots and bars on back. A bright reddish plum-colored area from middle of interorbital to tip of snout; similar spots on nape, opercles, and base of pectoral; a tinge of the same color between bars on back. Belly and chin greenish blue; tail reddish brown with white cross markings; lower part of pectoral orange yellow. Other specimens were darker and without much of the red color, but with many milk white spots.

The genus *Eximia* (to which this species was originally assigned) founded on specimens having the preopercular spine three pointed is not valid. Our specimens from Point Loma have both two- or three-pointed preopercular spines, and one specimen has a two-pointed spine on one side and a three-pointed spine on the other. The typical specimens from Pacific Grove, in the Stanford University collections, range from an imperfectly developed three-pointed spine to a well developed four-pointed spine.

Specimens of *Oligocottus maculosus* from Neah Bay, Washington, and of *Dialarchus snyderi* from Pacific Grove, California, occasionally have three-pointed preopercular spines. In some cases the third spine is very small and appears to be an outgrowth from the lower fork of the bifid spine. In others it is as well developed as in the typical *Eximia*.

191. **Blennicottus recalvus** Greeley.

(Jordan and Evermann, 1900, IV, p. 3178.)

Several small specimens, the longest 1½ inches in length, taken by Dr. W. W. Thoburn at the Coronado Islands. We did not see it on the mainland. It is probable that the records of *Blennicottus globiceps* this far south refer to this species, or possibly to *Oligocottus rubellio*. The range of this species is northward to Santa Cruz (Greeley, 1899, p. 9). It is abundant in Monterey Bay.

Family AGONIDÆ.

192. **Averruncus sterletus** Gilbert.

(Jordan and Evermann, 1898, II, p. 2071, figs. 750–750*a*.)

The type of this species, 4½ inches in length, was taken by the U. S. S. Albatross at a depth of 45 fathoms near the Coronado Islands.

193. **Xeneretmus*** **pentacanthus** (Gilbert).

(*Xenochirus pentacanthus* Jordan and Evermann, 1898, II, p. 2080.)

Specimens from San Pedro. This species may be known at once from *Xeneretmus latifrons*, the only other species of the genus found on the south coast, by the rostral plate having three upright spines. It reaches a length of 7 inches.

In the synonomy of this species given by Jordan and Evermann the typical specimens are stated to come from Bering Sea and off San Diego. They came from the coast of Washington a

* The generic name *Xenochirus* being preoccupied has been replaced by *Xeneretmus*.

little south of Cape Flattery (Albatross Station 3076). Specimens have since been taken from the Straits of Fuca, from off Oregon, the Santa Barbara Islands, and San Diego (Gilbert, MS. notes).

194. **Xeneretmus latifrons** (Gilbert).

(*Xenochirus latifrons* Jordan and Evermann, 1898, II, p. 2082.)

The types taken by the U. S. S. Albatross in deep water off Oregon and San Diego in from 50 to 204 fathoms. The largest specimen is 7½ inches in total length. The rostral plate has one upright spine.

195. **Odontopyxis trispinosus** Lockington.

(Jordan and Evermann, 1898, II, p. 2085.)

Specimens from off Point Loma and San Pedro. The origin of the anal in our specimens is as described for the typical specimens, opposite front of second dorsal, or one pair of plates farther forward; not "about one pair of plates behind front of second dorsal," as stated by Jordan and Evermann.

This species is common to Puget Sound (Jordan and Starks, 1895, p. 827) in water of moderate depths. Length about three inches.

Family GOBIIDÆ.

196. **Rhinogobius nicholsii** (Bean).

(*Gobius nicholsii* Jordan and Evermann, 1898, III, p. 2218.)

Three specimens from San Pedro. This goby is known from the coast of British Columbia, but has never been recorded southward before, though it is apparently common. Dr. Gilbert (MS. notes) has numerous records of its occurrence on the Southern California coast. It grows to a length of three inches.

197. **Zonogobius zebra** (Gilbert).

(*Gobius zebra* Jordan and Evermann, 1898, III, p. 2226.)

A specimen from San Clemente Island one inch in length. It has not before been recorded north of the southern part of Lower California (its type locality). It and a specimen 1½ inches long

from Todos Santos Island, Mexico, agree in all essential respects with the description of the type (7, p. 73), but show the following variations; the measurement appearing first is of the San Clemente specimen. Head 3¼ and 3⅔ in length to base of caudal; depth 4¾ and 4¼. Eye 3½ and 3⅔ in head. Dorsal VI, 12 and 13; and 10 and 9. Cross-bars on head and body 16 and 15.

This is a strongly marked goby and may be at once known by its color. It has narrow cross-bars on head and body, and a narrow cross line through each interspace between the bars. It is known from the Galapagos Islands (Snodgrass and Heller, 1905, p. 416), but has not been taken between that region and Mexico.

198. **Gobionellus sagittula** (Gunther).

(*Gobius sagittula* Jordan and Evermann, 1898, III, p. 2228.)

Several specimens were taken in a brackish slough in San Diego Bay near Old Town. It has not been hitherto recorded north of the Gulf of California. Small specimens a couple of inches in length have a larger eye and a shorter caudal than the large ones, agreeing in all respects with the original description by Gunther (1861, p. 372). Large specimens up to four inches in length agree with the description by Jordan and Evermann, but have 58, not 66 series of scales.

This goby is very widely distributed, being found in brackish water southward to the coast of Ecuador (Starks, 1906, p. 799). The adults may be at once distinguished from any other goby in our region by the long, pointed caudal. It reaches a length of 8 inches.

199. **Lythrypnus dalli** (Gilbert).

(*Gobius dalli*, Jordan and Evermann, 1898, III, p. 2230.)

A single specimen 1½ inches in length taken at San Pedro. It differs somewhat from the description of the type (Gilbert, 1890, p. 73). The soft dorsal is longer, having 20 rays rather than 17; the spinous dorsal is elevated in front, the spines growing gradually shorter posteriorly. The longest spine reaching to base of seventh ray, not the first two produced, reaching beyond middle of soft dorsal; the caudal is as long as the head, not less

than length of head; the third cross-bar runs downward from between the last two spines of dorsal, not from under middle of spinous dorsal; the scales number 47 in the lateral line, not 40. A decided median crest extends from the dorsal between the anterior margin of the eyes.

A specimen from Catalina Island in the Stanford University collections has the soft dorsal of 18 rays, and the medium crest is interrupted at the occiput. Three specimens 7/8 of an inch long from the Gulf of California have the soft dorsal of 17 rays; the scales in the lateral line from 44 to 47; the condition of the dorsal spines and the position of the third bar as in our San Pedro specimen; the median crest not extending on to the head as in larger specimens.

Known only from the above localities. Dr. Gilbert has recently observed it in abundance in Catalina harbor. It is a conspicuously marked form, and may be known by the narrow, sharp, dark bands across the head and anterior part of the body. It is not known to exceed 1½ inches in length.

200. **Lepidogobius lepidus** (Girard).

(Jordan & Evermann, 1898, III, p. 2249.)

Specimens examined from off San Diego. It is found northward to Puget Sound (Jordan & Starks, 1895, p. 839), and is sometimes seined in large numbers about San Francisco and used as food.

201. **Gillichthys mirabilis** Cooper.

(Jordan & Evermann, 1898, III, p. 2250.)

This species was taken in abundance in a slough which received some fresh water near Old Town, but was not seen by us in any other part of San Diego Bay, though other localities having similar conditions were seined. In Newport Bay it was found more widely distributed. Small specimens of a couple of inches in length resemble *Quietula y-cauda*, but may be known by the smooth ridge on the inner edge of the shoulder girdle, the short anal fin of from 11 to 13 rays, and by the color. At this age the maxillary is not greatly elongate, and the occipital region is not

MEASUREMENTS IN HUNDREDTHS OF LENGTHS.

LOCALITY	SAN DIEGO BAY										SANTA BARBARA						HORSESHOE BEND, COL. RIVER TYPES OF S. DETRUSUS					
Length to base of caudal in millimeters	104	107	72	111	85	89	109	73	73	113	106	88	86	89	87	90	85	99	80	101	76	101
Length of head in hundredths of length	34	32	31	35	33	34	32	32	33	34	32	33	33	34	32	34	31	32	31	33	32	32
Width of head	20	21	19	19	21	22	20	20	21	21	21	21	22	21	23	22	19	19	21	20	19	21
Width of interorbital bone	3½	4½	4½	4½	3½	4½	4	3½	4½	4½	4	4½	4½	4½	4	4	4½	4½	4½	4½	4½	4½
Width of entire interorbital space	7½	7½	8	8	7½	7½	7½	8	8	7½	8	8	8	8	8	8	8	7½	7	8	7	7½
Length of space between dorsals	9½	9	9	10	10	10	10½	9½	10½	9½	9½	8½	9	9	9	9½	9	11	10	11	11	9
Depth of caudal peduncle	11½	12	12	12	12½	12½	12	11½	12	12	11½	11½	12	12	12½	12	11	11	10½	11½	12	11
Number of dorsal spines	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI	VI
Number of dorsal rays	14	14	14	13	13	14	13	14	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Number of anal rays	13	13	13	12	12	13	12	13	12	13	12	12	12	12	11	12	12	12	12	12	11	12

depressed and keeled. Specimens examined from Mendocino County, 1¾ inches in length, contained mature eggs.

We are unable to distinguish between this species and *Gillichthys detrusus* Gilbert and Scofield. None of the alleged differences are valid except that of color, the latter species being everywhere lighter. *Gillichthys detrusus* can not therefore be considered as a separate species.

This species is known from Puget Sound (Jordan & Starks, 1895, p. 839) to the Gulf of California (Evermann & Jenkins, 1891, p. 162), living in burrows on the mud flats. The adults may be known at once by the long maxillary, which reaches in the larger specimens past the gill opening.

202. **Quietula y-cauda** (Jenkins and Evermann).

(Jordan & Evermann, 1898, III, p. 2251.)

This species was found everywhere abundant in San Diego Bay. It differs from *Ilypnus gilberti* and *Clevelandia ios* in being generally larger and in having the occipital region of the skull keeled, rather than transversely rounded. From the former it differs in having one or two more flaps on the inner edge of the shoulder girdle; in the body being stouter; and in color. From the latter it may be known by its having flaps rather than papillæ on the shoulder girdle.

The first dorsal usually has 5 spines, but in one specimen from San Luis Gonzales Bay there are 6; the soft dorsal usually has 15 rays, or rarely 16; the anal has 14, or sometimes 15 rays. There is a series of elongate spots along the median line of the side, the one at the base of the caudal being Y-shaped.

There is a wider range of variation in this species than in the other related forms. Some San Diego specimens are more elongate in form and usually darker colored than others. Some have very dark heads, especially on the under side, while the body is uniformly light, or moderately dark; large dark spots on pectoral and ventral, and a very dark anal with a light border.

The type, which the U. S. National Museum has loaned us, agrees in coloration with our light specimens. We have also re-

examined the type of *Gillichthys guaymasiae* Jenkins and Evermann. It is without doubt referable to this species, though it is larger than any we have seen. *Quietula y-cauda* is found from Vancouver Island (Jordan & Starks, 1895, p. 839) to Guaymas, Mexico (the type locality), and is everywhere abundant on the mud flats southward.

203. **Ilypnus gilberti** (Eigenmann and Eigenmann).

(Jordan & Evermann, 1898, III, p. 2253.)

This form was taken in abundance in San Diego Bay in company with *Quietula y-cauda* and *Clevelandia ios*. It has a conspicuous dark metallic spot on the opercle, which is never absent either in fresh or alcoholic material, and serves as a convenient means of identification. It differs from *Quietula y-cauda* in having only one, rarely two, dermal flaps on the inner edge of the shoulder girdle, in having the occipital region of the cranium transversely smooth and rounded, and in being more slender and more uniformly colored. From *Clevelandia ios* it differs in having flaps instead of papillae on the inner edge of the shoulder girdle, and in being generally darker.

The dorsal has nearly always 5 spines, occasionally 4, and 15 or 16 rays; the anal has usually 15 rays, sometimes 14, and rarely 16. Most specimens do not have enlarged dark spots, the entire body and fins being dusted over with fine dark points, which form a more or less complete network of broken lines, but occasional specimens have from 3 to 6 large dark spots along the base of the dorsal. The anal is dark toward the tips of the rays, and is with or without a white border. The type which we have examined has the usual dark spot on the opercle, and a dark anal, but some specimens from the type locality do not have the latter character. Specimens from Shoal Point, Colorado River; Conception Bay, L. C.; and San Bartolome Bay have less color than our San Diego specimens, especially on the anal.

This species is known from San Pedro south to the Gulf of California.

204. **Clevelandia ios** (Jordan and Gilbert).

(*Clevelandia rosæ* Jordan and Evermann, 1898, III, p. 2254, fig. 793 (poor). See Gilbert, 1904, p. 263, for synonomy and discussion of species.)

This species is very abundant in all parts of San Diego and Newport bays. The young in great numbers are left by the tide in pools in the sand. It may be known from the other closely related gobies found with it by its uniform light sand color dusted over with black, its more slender body, and three or four papillae on the inner edge of its shoulder girdle. These papillae do not resemble the long finger-like flaps found on the shoulder girdle of *Ilypnus gilberti* and *Quietula y-cauda*. From *Ilypnus gilberti*, which it resembles most closely in size, coloration, and in having the occipital region transversely smooth and rounded, it may be readily distinguished by the absence of a metallic spot on the opercle; the body is a littel more slender and cylindrical and the dorsals are usually a little farther apart.

Dorsal IV or V very rarely VI, 15 or 16, rarely 17; anal 15 or 16.

This species is found from Vancouver Island to San Diego Bay; abundant southward. It was originally described from a specimen found in the stomach of *Hexagrammos asper* at Vancouver Island.

205. **Typhlogobius californiensis** Steindachner.

BLIND GOBY.

(Jordan and Evermann, 1898, III, p. 2262, fig. 795.)

This species is rather abundant in a small area, extending one or two hundred yards along the shore of the bay side of Point Loma, where it lives under the rocks in holes and runways made by crustacea. One specimen seen swimming slowly over the bottom of a small, clear rock pool in the bright sunlight on the ocean side of Point Loma, near the outer lighthouse. Dr. Ritter reports this fish common at Point Firmin, living there as at Point Loma.

Family ECHENEIDIDÆ.

206. **Echeneis remora** Linnæus.

REMORA.

(*Remora remora* Jordan and Evermann, 1898, III, p. 2271.)

Reported by Dr. Eigenmann (1892, p. 148) to be common at San Diego in summer. It is of cosmopolitan distribution.

Family MALACANTHIDÆ.

207. **Caulolatilus princeps** (Jenyns).

(Jordan and Evermann, 1898, III, p. 2276.)

This species is commonly taken off Point Loma. It is abundant from Monterey to Cape San Lucas, and from the Galapagos Islands (type locality) to the coast of Peru (Starks, 1906, p. 799), but between Cape San Lucas and the Galapagos Islands it is unknown. We have compared specimens from our coast with specimens from Peru, but can appreciate no difference.

Family BATHYMASTERIDÆ.

208. **Rathbunella hypoplecta** (Gilbert).

(Jordan and Evermann, 1898, III, p. 2290.)

A single specimen known, eight inches in length, taken by the U. S. S. Albatross in thirty fathoms of water off the Santa Barbara Islands.

Family BATRACHOIDIDÆ.

209. **Porichthys notatus** Girard.

MIDSHIPMAN.

(Jordan and Evermann, 1898, III, p. 2321.)

Common. Young specimens have thirteen dark cross-bars on body between head and tip of caudal, with slight traces of two similar ones across head. Abundant from Puget Sound (Jordan and Starks, 1895, p. 840) to the Gulf of California (Evermann and Jenkins, 1891, p. 162); living under stones and in tide pools

northward, in deeper water southward. The shining spots along the sides and ventral region of this fish have suggested brass buttons, and given to it its common name, midshipman. It is also called singing-fish, on account of the loud humming noise it makes when disturbed.

Family GOBIESOCIDÆ.

210. **Gobiesox papillifer** Gilbert.

(Jordan and Evermann, 1898, III, p. 2330.)

One specimen 2 inches long from San Pedro. It has hitherto been known only from Magdalena Bay, Lower California. It shows the following variations from the description of the type (Gilbert, 1890, p. 96). The anal has 10 rays (not 9); the eye is ⅔ of interorbital width (not ½). The bars on the vertical fins are very indistinct; the white bar said to follow the black bar at base of fins can not be distinguished from the dusky area following; the white margin is evident.

211. **Rimicola eigenmanni** (Gilbert).

(Jordan and Evermann, 1898, III, p. 2339.)

Known only from a single specimen, the type, taken at Point Loma and from specimens taken at San Cristobal Bay (Smith, 1884, p. 553, under the name of *Gobiesox rhessodon*).

212. **Arbaciosa rhessodon** (Rosa Smith).

(Jordan and Evermann, 1898, III, p. 2340.)

Specimens taken in abundance in tide pools on the ocean side of Point Loma, at La Jolla, and San Pedro.

A cotype in the collections of Stanford University is identical with our specimens, but differs from the original description (Rosa Smith, 1881, p. 140) in having the eye $^{6}/_{100}$ of the total length to base of caudal, not $^{3}/_{100}$. It differs from the description by Jordan and Evermann in having the head contained 2⅘ times in body, not 3¼ times; the eye 6 times in head, not 4½ times.

It is found in abundance in rock pools southward to San Bartolome Bay, Lower California.

Family BLENNIDÆ.

213. **Heterostichus rostratus** Girard.

KELPFISH.

(Jordan and Evermann, 1898, III, p. 2351.)

Common in San Diego Bay. The young was not seen in the winter, but was seldom absent from the contents of a seine in the summer.

Color in life: ground color light green; yellow on belly and under parts. Back and sides with 3 or 4 longitudinal dark green stripes, more or less broken up into spots, darker toward the edges, and outlined with white. A similar stripe running from snout through eye to upper end of gill opening. A white spot on base of middle pectoral rays; dorsal and anal mottled with alternate dark green and translucent spots; tip of mandible dark.

This species may be known from other blennies by the prominent hook-like process on the inner edge of the shoulder girdle, together with the forked tail. It reaches a length of 18 inches, and is abundant from San Francisco to Guadalupe Island (Jordan and McGregor, 1898, p. 284).

214. **Gibbonsia elegans** (Cooper).

SPOTTED KELPFISH.

(Jordan and Evermann, 1898, III, p. 2353.)

Common along the coast south of Point Conception; a single specimen from Monterey Bay.

We can not agree with the late Mr. A. W. Greeley (1899, p. 20), who has reported this species inseparable from its northern representative *Gibbonsia evides*. An examination of many specimens from San Diego, San Clemente Island, San Pedro, and Monterey Bay shows that there are two closely related but distinct species.

Gibbonsia elegans differs from *Gibbonsia evides* in being generally smaller in size, somewhat deeper in appearance, having a rounder contour of front part of head and snout, a larger eye, higher dorsal and anal fins, and of more varied and brilliant coloration. The fin rays average less; the dorsal has from 27 to 29

spines and from 6 to 9 soft rays. In *Gibbonsia evides* the dorsal has from 29 to 31 spines and from 7 to 10 soft rays. In the former species the anal has from 22 to 25 rays, while in *Gibbonsia evides* it has from 26 to 28 rays. The alleged greater extent of the pellucid area of the soft dorsal of *Gibbonsia elegans* can not be used to separate the species. Though in the average it is larger and more usually present in that species, any condition of it found in one species may be found in the other.

The species overlap in geographical range; three specimens of *Gibbonsia evides* were found at San Diego among a couple of hundred of *Gibbonsia elegans*, and one of the latter species was found at Monterey Bay among about a hundred of the former species.

The most common coloration of *Gibbonsia elegans* is as follows: Dark brown with red shades above lateral line and green below; belly, yellow or white. Irregular cross-bars mottle the sides; these are usually outlined with light blue, green, or yellow. Lower part of head and body usually spotted or reticulated with white. An ocellated spot nearly always present behind opercular flap, another under posterior fourth of spinous dorsal, and often one (usually smaller) under front of soft dorsal; these black or dark green and ringed with red. Some specimens are light maroon without cross-bars or other markings, except usually the ocellated spots, which when present are blue or brown in the middle, and ringed with dark brown, red, or blue, or sometimes with all of these colors. Membrane of caudal very light brown, spotted with round transparent spots; the rays of caudal colored like body. Last dorsal rays transparent; transparent areas on spinous dorsal at regular intervals, growing small and disappearing posteriorly; dark bars on pectoral and ventral. A silvery line running backward from eye often present. Other specimens similar to the above, but the prevailing color dull greenish drab, with or without traces of longitudinal lines. The ocellated spots green in the center, ringed with bright red. Rarely specimens are everywhere bright moss green with irregular longitudinal white lines in pairs, inclosing between each pair darker green. Bright green markings on fins. The ocellated spots dark green, ringed with very bright red. The young up to two inches in length are

often black on back, shading to very dark seal brown on sides; belly rosey. A narrow, bright silvery streak, its edges sharp, nearly as wide as eye, runs backward from eye across cheek, thence longitudinally through middle of body to opposite middle of anal. The last dorsal rays transparent as usual. Occasionally traces of the silvery streak are present in adults.

TABLE OF FIN RAYS.

	Number of specimens counted	Number of dorsal rays	Number of anal rays
San Diego Bay	16	V, XXVIII, 7	II, 24
	15	V, XXVIII, 8	II, 24
	4	V, XXIX, 7	II, 24
	4	V, XXVIII, 8	II, 25
	3	V, XXIX, 8	II, 24
	3	V, XXIX, 7	II, 25
	3	V, XXVII, 7	II, 25
	2	V, XXIX, 6	II, 24
	2	V, XXVIII, 7	II, 23
	1	V, XXIX, 8	II, 25
	1	V, XXVIII, 8	II, 22
	1	V, XXVII, 9	II, 24
	1	V, XXVII, 8	II, 24
Monterey Bay	1	V, XXVII, 8	II, 25

MEASUREMENTS IN HUNDREDTHS OF LENGTH TO BASE OF CAUDAL.*

Part of Body	San Diego Bay					San Pedro				Monterey
Length to base of caudal in mm	108	100	90	103	197	97	107	79	95	107
Length of head in hundredths of length	22	23	23	24	24	24	23½	24	24½	24½
Diameter of eye	6	5	6	5½	5½	6	5½	6	5½	6
Highest spine of dorsal	11½	11½	11½	12½	10	11	12	13	11½	10
Highest ray of dorsal	13½	12½	12	13½	12	13	13	13½	12½	12
Highest ray of anal	12	11	12	12½	11	11½	11½	12	11½	11½

*Many more specimens were measured and counted than are shown here.

215. **Gibbonsia evides** (Jordan and Gilbert).

SENORITA; KELPFISH.

(Jordan and Evermann, 1898, III, p. 2352.)

Three specimens taken at San Diego. This species has not been hitherto known south of Point Conception. Dorsal, V, XXIX to V, XXXI, 7 to 10; anal II, 26 to 27.

Color in life: usually dark wine color or dark reddish brown, with irregular cross mottlings of darker on sides; the colors not blended, but sharp-cut against each other. Small irregular golden or silvery spots usually present on lower part of sides, but often absent; small light spots on lower part of head. Dorsal and anal with broad cross marks on the dark body color; transparent in the intervals. Some specimens uniform dark reddish brown, without markings; lighter below; transparent areas on fins reduced to small dots. Some specimens moss green on back and sides; a longitudinal band of pure lavender, bordered above and below with lighter, on upper part of side, becoming narrow posteriorly and reaching a point opposite soft dorsal. It is much constricted at irregular intervals, or sometimes broken into oblong spots. A round black sopt ringed with dark red above base of pectoral; another under posterior end of spinous dorsal; a smaller one under front of soft dorsal. Some or all of these often absent. Lower part of sides mottled irregularly with moss green and lavender; the colors nowhere blended into each other; the lavender abruptly lighter at edges, the green slightly darker. Irregular points of pure white sparsely scattered over sides. Four dark bands radiating from eye; one to nape; one to opercular flap; one to snout; one downward and slightly forward. Large and small irregular silvery white spots on sides of belly. Dorsal and anal with nearly vertical dark bars across the rays; those on dorsal lavender, on anal dark brown. The intervals between the bars on dorsal transparent, mottled with small dark markings; the intervals on anal with a few fine bright orange spots. Front of soft dorsal dark brown; pink at tips of rays; posteriorly the membrane is transparent; the rays are spotted. Caudal and pectoral with irregular cross markings of reddish brown.

TABLE OF FIN RAYS.

	Number of specimens counted	Number of dorsal rays	Number of anal rays
Monterey Bay	10	V, XXXI, 9	II, 27
	12	V, XXXI, 9	II, 26
	4	V, XXX, 9	II, 27
	4	V, XXX, 8	II, 26
	4	V, XXX, 7	II, 26
	4	V, XXX, 7	II, 27
	3	V, XXX, 8	II, 27
	3	V, XXX, 7	II, 26
	2	V, XXXI, 10	II, 28
	2	V, XXXI, 10	II, 27
	2	V, XXIX, 8	II, 26
	1	V, XXXI, 9	II, 28
	1	V, XXXI, 8	II, 27
	1	V, XXXI, 8	II, 26
	1	V, XXX, 10	II, 26
	1	V, XXX 9	II, 26
	1	V, XXX, 8	II, 28
	1	V, XXIX, 8	II, 27
San Diego Bay	1	V, XXX, 10	II, 28
	1	V, XXX, 9	II, 27
	1	V, XXX, 9	II, 26

MEASUREMENTS IN HUNDREDTHS OF LENGTH TO BASE OF CAUDAL.

Part of Body	Monterey Bay					San Diego Bay
Length to base of caudal in mm.	113	70	132	119	127	78
Length of head in 100dths of length	25	22	24½	23½	23	24½
Diameter of eye	4	5½	4½	4½	4½	5
Highest spine of dorsal	9	12	9½	9	8½	9½
Highest ray of dorsal	11	11	11	10½	10½	12
Highest ray of anal	10½	10½	10½	9	9½	10

216. **Neoclinus blanchardi** Girard.

(Jordan and Evermann, 1898, III, p. 2354.)

Not rare from Monterey (Jordan and Gilbert, 1880, p. 454) to San Diego (type locality). This species differs from *Neoclinus satiricus* in having no spot behind the seventh spine of dorsal; in having the membrane of lower lip, which is covered by the maxillary, white (black, edged with white in *Neoclinus satiricus*); in

having the head and maxillary shorter, and the barbels in the male much longer.

217. **Neoclinus satiricus** Girard.

(Jordan and Evermann, 1898, III, p. 2355, fig. 816.)

Several specimens of the young of this species were taken at San Pedro. A specimen 1½ inches long has the maxillary reaching the posterior border of the pupil; in specimens from 1¾ to 2¼ inches the maxillary reaches a considerable distance past eye.

Color in spirits uniform, with small definite black spots along base of dorsal and on top of head; ten wide brown bars extend across anal; dorsal uniform light slate color; caudal light with a dark tip.

It is found northward to Monterey (type locality), and reaches a length of 10 inches.

218. **Starksia holderi** Lauderbach.

(Jordan and Starks, 1906; in press.)

The type from Avalon is the only specimen known.

219. **Cryptotrema corallinum** Gilbert.

(Jordan and Evermann, 1898, III, p. 2366, fig. 817.)

Known from the Santa Barbara Islands, where it was taken by the U. S. S. Albatross in thirty fathoms of water.

220. **Auchonopterus integripinnis** (Rosa Smith).

(Jordan and Evermann, 1898, III, p. 2372.)

Numerous specimens from the tide pools of Point Loma, La Jolla, and San Clemente Island. The dorsal is composed wholly of spines, as stated in the original description (Smith, 1880*a*, p. 147). The one soft ray mentioned by Jordan and Evermann is rarely present and only as a very small rudiment.

Color in life: brown on body, with more or less distinct cross-bars of darker brown; usually 2 or 3 rather bright, diffused orange cross spots on middle of side behind tip of pectoral between the dark bars. A plum-colored or brick-red area on opercles and top of head. Base of pectoral reddish, its distal half or more yellow; caudal yellowish or sometimes reddish. Small

spots on pectoral, caudal, and ventral rays, making wavy, irregular lines across fins. A black spot on posterior part of dorsal narrowly ringed with yellow, outside of which is often a dark ring. Anal brownish, with darker cross spots at regular intervals; the edge of fin margined with bright yellow. Some specimens are nearly everywhere coal black; the belly slightly lighter; the distal half of pectoral dark green; the caudal and edge of anal abruptly light red; the ocellated dorsal spot nearly obsolete.

This species is known from San Pedro to San Cristobal, Lower California.

221. **Hypsoblennius gilberti** (Jordan).

(Jordan and Evermann, 1898, III, p. 2386.)

Taken in abundance in tide pools on the ocean side of Point Loma, and at San Pedro; not found in the open bays.

The species may be known from *Hypsoblennius gentilis* by the almost straight profile of head from tip of snout to between eyes, and by the multifid tentacle over eye. The sexes do not greatly differ; the tentacle of the male is somewhat longer than that of the female, but the tentacle of the latter is much longer than in the female of *Hypsoblennius gentilis*. The two anal spines of the male are provided with fleshy tips. It is known from Santa Barbara (type locality) to Todos Santos Bay, Lower California (Smith, 1883, p. 235). It does not exceed six inches in length.

222. **Hypsoblennius gentilis** (Girard).

(Jordan and Evermann, 1898, III, p. 2387.)

Common at San Diego and San Pedro in the open bays; no specimens seen in rock pools with *Hypsoblennius gilberti*. This species may be known from *Hypsoblennius gilberti* by the rounded profile of head from tip of snout to above eyes, and by the simple fringed tentacle above each eye.

The males have the two spines of anal partly free and provided with fleshy tips, and the supraorbital tentacle long and slender. Color in life: anterior half of body and head thickly set with sharp-cut round spots of black or dark brown, narrowly separated from each other by fine olive green lines of the ground

color. On the posterior half of the body the brown color is dusky bluish, irregularly spotted and mottled with lighter slaty bluish. On the back are the beginnings of 6 or 7 faint cross bands. A faint dusky shade downward from eye and another backward; tip or lower jaw with a large, bright vermilion spot. Across lower part of head, running down from a level with mouth, are four light cross shades; the two posterior ones sharply defined and bright yellow margined with brown; the anterior ones, white and a little diffused. Anal blackish, very slightly mottled, the tips of the rays white; the swollen anterior spines flesh-colored. Pectoral light, mottled with dusky green; ventral dusky, the outer ray white; caudal yellow. Dorsals uniform, with or without a scarcely conspicuous dusky blue spot in front of spinous dorsal, or dorsals sometimes marked like body under them, though the spots on spinous dorsal are smaller and more widely spaced than those on body.

Females have a very short, simple tentacle over eye, sometimes almost absent; no small spots or reticulations on anterior part of the body and head. The light bars on under part of head are broader and blend softly with the dark interspaces. Front of spinous dorsal with a very definite dark spot.

A few males were found which much resemble females in length of supraorbital tentacles, character of bars on under side of head, and definite dark spot on front of anal.

This species is found from Monterey (type locality) to Guaymas, Mexico (Evermann & Jenkins, 1891, p. 163). It is common southward in shallow water of the open bays.

223. **Ulvicola sanctae-rosae** Gilbert and Starks.

(Jordan & Evermann, 1898, III, p. 2413.)

Known only from a single specimen collected at Santa Rosa Island.

224. **Xererpes fucorum** (Jordan and Gilbert).

(Jordan & Evermann, 1898, III, p. 2413.)

Dr. Gilbert (MS. notes) records this species from Santa Rosa and San Clemente Islands. Not before recorded south of Monterey (type locality). It is known northward to Puget Sound

(Jordan & Gilbert, 1880, p. 454). This is one of the two or three records of the occurrence of elongate blennies off the southern coast. None of the specimens have been taken in shallow water on the mainland, where they are found so abundantly northward. It is a distribution apparently parallel with that of *Blennicottus recalvus* (a species abundant in tide pools at Monterey Bay), which we did not take on the mainland, though it is common on the Coronado Islands.

225. **Chaenopsis alepidotus** (Gilbert).

(*Lucioblennius alepidotus* Jordan and Evermann, 1898, III, p. 2404.)

The adult of this species has recently been described (Jordan and Starks, 1906) from specimens collected at Avalon, Santa Catalina Island. It had previously been known from two very small specimens from the Gulf of California.

226. **Poroclinus rothrocki** Bean.

(Jordan & Evermann, 1898, III, p. 2434.)

A specimen recorded by Dr. Gilbert (MS. notes) from off San Diego. It has hitherto been known only from Bering Sea.

Family ZOARCIDÆ.

227. **Embryx crassilabris** Gilbert.

(Jordan & Evermann, 1898, III, p. 2458.)

Known from a single specimen, 12 inches long, taken off Southern California.

Family OPHIDIIDÆ.

228. **Chilara taylori** (Girard).

(Jordan & Evermann, 1898, III, p. 2489.)

Reported by Eigenmann (1892, p. 173) to be taken sometimes in San Diego Bay; not seen by us. This species reaches a length of 12 inches and is not rare in water of moderate depth north to Monterey Bay.

Family LYCODAPODIDÆ.

229. **Lycodapus fierasfer** Gilbert.

(Jordan & Evermann, 1898, III, p. 2493.)

The typical specimens from the Gulf of California, off Southern California and Washington in very deep water. Dr. Gilbert (MS. notes) records it in one station off Southern California in water shallow enough (27 fathoms) to admit it to this list.

Family MERLUCCIIDÆ.

230. **Merluccius productus** (Ayres).

HAKE.

(Jordan & Evermann, 1898, III, p. 2531, fig. 884.)

Specimens taken on lines in deep water a few miles off Point Loma. The hake or merluccio (its Italian name) is irregular in its appearance, being some years very abundant northward, and others altogether wanting. It is probably never common on the southern coast. It reaches a weight of 10 pounds, though its average weight is about half that. As a food fish it is of little value, as its flesh is very soft and watery, and it is always ragged looking when shipped. The fishermen never save it when other fish are to be had. It is exceedingly voracious, feeding on all sorts of small fishes and squids.

A specimen in the collection of Stanford University, from the Gulf of California (Albatross Station 3007) extends the range of this species southward. It ranges northward to Puget Sound (Jordan & Starks, 1895, p. 850).

Family PLEURONECTIDÆ.

231. **Lyopsetta exilis** (Jordan and Gilbert).

(Jordan & Evermann, 1898, III, p. 2612.)

Two specimens taken off San Pedro. It ranges northward to Puget Sound (Jordan & Starks, 1895, p. 851), is abundant about San Francisco, and is known southward to San Diego (Gilbert, MS. notes). It does not exceed a foot in length, and is of little value as a food fish.

232. **Eopsetta jordani** (Lockington).

ENGLISH SOLE.

(Jordan & Evermann, 1898, III, p. 2613.)

Once recorded from San Diego by Eigenmann (1890, p. 23). North of Monterey this is an abundant and important species; reaching a length of 20 inches. As a food fish it is considered one of the best of the flounders. Great numbers are dried yearly by the Chinese. It ranges northward to Puget Sound (Jordan & Starks, 1895, p. 850.) Its common name "English sole" is doubly unfortunate, as it is not a sole, and is not found in England.

233. **Hippoglossina stomata** Eigenmann and Eigenmann.

(Jordan & Evermann, 1898, III, p. 2620.)

The typical specimens taken in deep water off San Diego. Dr. Gilbert (MS. notes) records it from numerous localities from off the southern part of Lower California north to Point Conception. It is apparently not rare in deep water.

234. **Xystreurys liolepis** Jordan and Gilbert.

(Jordan & Evermann, 1898, III, p. 2623.)

Specimens from San Pedro. This species reaches a length of 15 inches and is rather common on the Southern California coast. It ranges from Santa Barbara (type locality) to the Gulf of California (Gilbert, MS. notes). It has not been before recorded so far south.

235. **Paralichthys californicus** (Ayers).

(Jordan & Evermann, 1898, III, p. 2625.)

The "halibut" of Southern California; a food fish of importance. The young is the commonest flat fish on the beaches of San Diego Bay. It reaches a weight of 60 pounds and a length of 3 feet. Known from San Francisco (type locality) to the head of the Gulf of California (Gilbert, MS. notes).

236. **Pleuronichthys verticalis** Jordan and Gilbert.

(Jordan & Evermann, 1898, III, p. 2638.)

Not rare in San Diego Bay; hitherto unrecorded this far south. It is not very common; ranging north to San Francisco (the type locality). It may be known from *Pleuronichthys cœnosus* by the higher, sharper interorbital space, with a higher, sharper spine at its posterior end. The records of *Pleuronichthys cœnosus* south of Point Conception probably refer to either this species or to *Pleuronichthys ritteri.*

237. **Pleuronichthys ritteri,** sp. nov.

Head 4⅕ in body to base of caudal; depth 1⅞. Upper orbit 3 in head; maxillary 4; pectoral of colored side 1⅗; highest dorsal ray 1½; highest anal ray 1½; caudal 1. Dorsal ray 66; anal rays 48. Scale in a longitudinal series above lateral line 78.

Ventral outline of body forming a nearly straight line from front of anal to tip of mandible; head pointed. Interorbital ridge low and sharp, ending posteriorly in a short conical spine turned slightly downward; a small tubercle on posterior margin of upper orbit; and two at anterior margin of lower orbit, the upper of which is the larger. A cutaneous fold on blind side close behind angle of mouth. Teeth present in bands on blind side of both jaws, and a narrow band on eyed side of lower jaw. Gill rakers 5 + 11.

Origin of dorsal on a level with anterior margin of maxillary; the first two rays below the level of upper nostril. Origin of anal slightly behind vertical from base of pectoral. Pectoral of blind side ⅔ as long as its mate; ventral of blind side slightly longer than its mate, and a little farther forward; caudal rounded. Scales small, cycloid, imbedded, and not imbricated anteriorly. Accessory branch of lateral line ending under thirty-forth dorsal ray.

Ground color in spirits grayish brown; light spots as large as pupil scattered over body and head; an indefinite dark spot slightly larger than pupil on lateral line midway between tip of snout and base of caudal; a larger spot under base of posterior fifth of dorsal and a similar one opposite it at base of anal. Dor-

sal and anal fins light, somewhat mottled with large blotches of darker brown; the shades blending into each other. Caudal mottled; a light spot on each side of base; a light bar across middle; its posterior half darker. Pectoral crossed by 3 light bars, the last bordering the fin. Edge of shoulder girdle dark below pectoral.

The above description is of the type, 6¼ inches in total length. Other specimens show the following variations: Head 4 to 4¾; depth 1⅘ to 1⅞. Dorsal 62 to 68; anal 46 to 48; scales 77 to 83; gill rakers 3 to 5 + 9 to 11. The dark spots may be indistinctly ocellated; the light spots may be absent. A small specimen has the entire body peppered with black, no light spots, and a black spot at posterior end of dorsal and anal.

This species may be known from *Pleuronichthys verticalis* by the shorter spines and tubercles on head, and the lower interorbital ridge not reaching to end of snout. From *Pleuronichthys cœnosus* by the more elongated head, the snout not continuous with dorsal outline, the presence of two anterior tubercles, and by the tendency of the posterior spine of interorbital to turn downward.

The type of this species was taken in San Diego Bay; it is numbered 9786 in the Stanford University collections. Cotypes were taken at the same locality, and at San Pedro.

We take pleasure in naming this species for Dr. W. E. Ritter, Scientific Director of the Marine Biological Station of San Diego.

238. **Pleuronichthys decurrens** Jordan and Gilbert.

(Jordan and Evermann, 1898, III, p. 2637.)

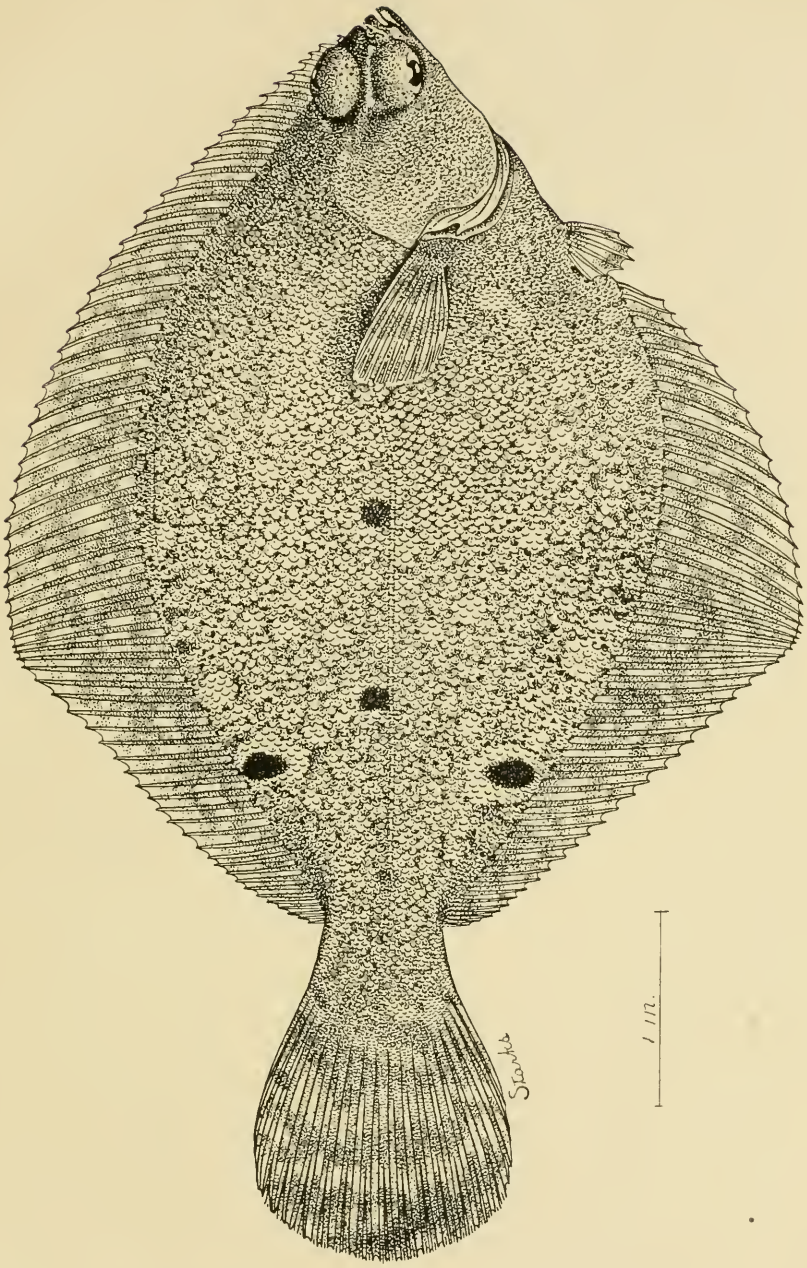
Known from San Francisco to the Santa Barbara Islands (Gilbert, MS. notes); hitherto unrecorded from Southern California. It may be readily known from other species of *Pleuronichthys* by the front of the dorsal extending farther down on the blind side of the head.

239. **Hypsopsetta guttulata** (Girard).

DIAMOND FLOUNDER.

(Jordan and Evermann, 1898, III, p. 2639.)

A common flounder on the shoal beaches of San Diego and



Pleuronichthys ritteri Starks and Morris, new species.
Drawn from the type from San Diego, by Chloe Lesley Starks.

San Pedro bays. Color in life: brown with round bluish spots scattered sparsely over the body, and arranged in more or less definite rows. A row of 3 or 4 along the lateral line at wide intervals; an arched row of 10 or 15 midway between lateral line and back, and a similar row between lateral line and ventral outline. Sometimes a few light spots and a row of obscure dark spots, or sometimes rings at base of dorsal and anal. Other specimens have the spots more scattered over the body; the spots do not show in preserved specimens.

This flounder is a food fish of fair quality; it is one of the common species in the shoal waters from Tomales Bay (type locality) to the head of the Gulf of California (Gilbert, MS. notes).

240. **Parophrys vetulus** Girard.

(Jordan and Evermann, 1898, III, p. 2640.)

Specimens from San Pedro. This flounder is found in great abundance; it lives in water of moderate depths and never reaches a large size. It is known from Alaska (Jordan, 1884, p. 185) to San Diego (Gilbert, MS. notes).

241. **Microstomus pacificus** (Lockington).

(Jordan and Evermann, 1898, III, p. 2655.)

Many adult specimens taken off San Pedro. A specimen 2¼ inches in length is apparently the young of this species. The eyes are symmetrical, one on each side of head. The head is small, contained six times in total length to base of caudal. The eyes and mouth much smaller than in the adult, though of about the same size in relation to the size of the head. Sharp recurved teeth are present on both sides of jaws. The number of dorsal and anal rays and vertebrae are the same as in the adult. The color is the same on both sides of the body, very pale with a row of dark brown spots on median line from above base of pectoral to base of caudal; those nearest head smaller and less distinct.

Specimens having all of the characters of the adult with the eyes and color on one side, are no longer, but have the body thicker and deeper; the head larger, 3½ times in body to base of

caudal; the eye larger; and broad incisor-like teeth on blind side only.

This species is hitherto unrecorded south of Monterey; it ranges northward to Unalaska (Gilbert, 1893, p. 460) and southward to San Diego (Gilbert, MS. notes). It is common in deep water and does not exceed a pound in weight.

242. **Glyptocephalus zachirus** Lockington.

(Jordan and Evermann, 1898, I, p. 2658.)

Records by Dr. Gilbert (MS. notes) extend the range of this species southward to Southern California. It is common northward to Bering Sea (Gilbert, 1893, p. 460).

243. **Citharichthys sordidus** (Girard).

(Jordan and Evermann, 1898, III, p. 2679, fig. 943.)

This flounder is very common in waters of moderate depths from British Columbia (Bean, 1884, p. 353) to Cerros Island, Lower California (Gilbert, MS. notes). It rarely exceeds two pounds in weight.

244. **Citharichthys stigmaeus** Jordan and Gilbert.

(Jordan and Evermann, 1898, III, p. 2681.)

Specimens from San Diego and San Pedro. They agree with the description of the type (Jordan and Gilbert, 1892, p. 411) in most respects, but have from 59 to 62 pores in the lateral line (not 54), and have scales on the posterior part of the interorbital ridge. A specimen taken by the U. S. S. Albatross off the coast of Oregon agrees with our specimens in these respects.

This species may be known from *Citharichthys sordidus* in having a sharp interorbital space. It is found in deep water from San Diego to Oregon, and is rather rare.

Family SOLEIDÆ.

245. **Symphurus atricaudus** (Jordan and Gilbert.

SAN DIEGO SOLE.

(Jordan and Evermann, 1898, III, p. 2707.)

Specimens taken by the aid of a trawl in abundance outside of San Diego Bay in about fifty fathoms. It probably seldom runs into shallow water, as it is unknown to the seine fishermen. It is known to the Gulf of California (Gilbert, MS. notes).

Family ANTENNARIIDÆ.

246. **Antennarius avalonis** Jordan and Starks.

(Jordan and Starks, 1906; in press.)

This species is known from the type 13½ inches in length from Avalon, Santa Catalina Island.

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BIOLOGICAL STUDIES ON CORYMORPHA

II.—THE DEVELOPMENT OF *C. PALMA* FROM THE EGG

BY

HARRY BEAL TORREY

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BIOLOGICAL STUDIES ON CORYMORPHA.—II. THE DEVELOPMENT OF *C. PALMA* FROM THE EGG.[1]

BY

HARRY BEAL TORREY.

I. — Introduction.

The present investigation was undertaken with the purpose of analyzing the processes which characterize the development of the embryo of *Corymorpha*, in order (1) to discover to what extent the form of the species might be determined by its activities, and (2) to compare the normal embryonic processes with those which appear in the regenerative development.

No definite attempt to determine the relations which might exist between the behavior, the normal and the regenerative development of any animal has been made heretofore, so far as I am aware. Morgan (:01*a*) called attention, in an essay in the American Naturalist, to the desirability of a systematic comparison of the processes of regeneration in egg, embryo and adult. He also emphasized the fact that little account had previously been taken of the problems involved in this sort of work. Shortly afterward, Schultz (:02) considered briefly, in the Biologisches Centralblatt, the relation between a number of phenomena of regeneration, normal development from the egg, and non-sexual reproduction. Subsequent theoretical discussions by Holmes (:04), and still more recently by Child (:06), have aimed at bringing all the phenomena of regulation under a common point of view.

In 1902 I began investigation in this field, with the conviction that normal activities also should form one element in the general

[1] Biological Studies on Corymorpha.—I. *C. palma* and Environment. Journ. Exp. Zool., I, No. 3, pp. 395-422.

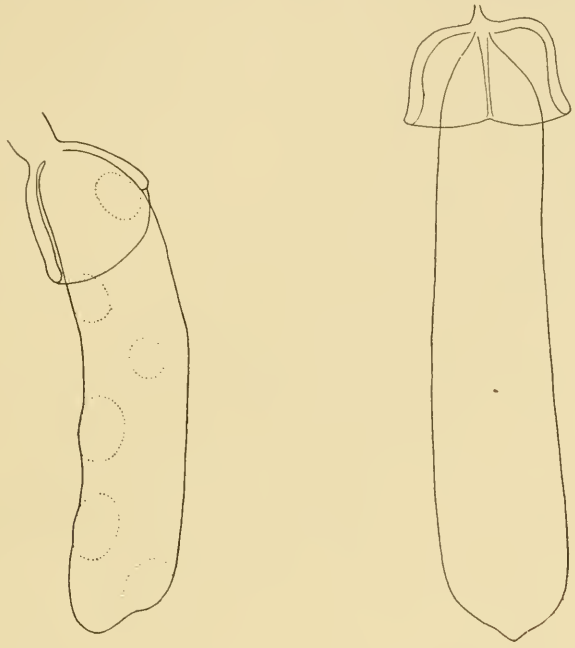
problem, and that the examination of a single favorable species from different points of view would yield interesting results. *Corymorpha* is a most satisfactory object for studies of this sort. Its behavior has been investigated somewhat already (Torrey, :04, :05), with certain unique results. The regenerative development includes special features of interest to the student of morphallaxis, and will be treated in a paper soon to follow. The present paper is concerned with the development from the egg, especially those phases of post-embryonic life which are also represented in the regeneration of the adult, such as the changes resulting in the establishment of the specific form of the body, its regions and characteristic organs. The early stages in the development, therefore, will receive but a scanty treatment here. In the absence, however, of anything but the most fragmentary records of the development of *Corymorpha*, it has seemed desirable to include a few observations on its prelarval history.

Although many naturalists have been more or less intimately acquainted with *Corymorpha* since Sars described *C. nutans* in 1835, its young remained unknown until three larval stages of the same species were described and figured by Allman (:71). These, including the sessile planula and polyps with six and sixteen proximal tentacles, he supposed to have sprung from detached rootlets, or frustules, instead of from eggs. The larva is so different from the adult, and resembles so closely a diminutive *Tubularia*, that it was described recently by Hargitt (:02) under the name of *T. parasitica*. The misconception was pointed out soon after in a letter to the American Naturalist (Torrey, :02*a*). May (:03) has published observations on the development of the medusa and the ovarian egg. The only other references to the subject are contained in two papers by the author (:02 and :04*a*). The former is a footnote, and the latter considers very briefly the features of the development which are concerned with a study of the behavior of the hydroid.

II. — The Medusa, Eggs and Egg-laying.

The medusa of *C. palma* (Figs. 1, 2), unlike those of the other species of the genus, is probably never liberated from the parent

hydroid. In common with the medusae of all hydroids where a similar condition obtains, it shows signs of degeneracy. Tentacles, sense organs and mouth are lacking, and the bell, in proportion to the manubrium, is very much smaller than usual. Otherwise the medusa is perfect. The bell not only possesses a ring and four radial canals, but from an early stage of development pulsates as vigorously as though it were free. Subumbrella



1 2

Fig. 1. Female medusa, with a number of unripe eggs outlined on the manubrium. × 58.

Fig. 2. Male medusa at maturity. × 58.

muscles still remain, therefore, and function actively—an interesting persistence of a habit which the species appears to have outgrown.

As in *C. pendula* (May, :03), the germ cells arise in the ectoderm of the manubrium from cells which are derived from the ingrowing ectodermic plug at the apex of the medusa-bud. Definitive ova result from the growth of some of these cells at

the expense of others. According to May, the latter are usually incorporated by a process of cytoplasmic fusion and subsequent disintegration of all the nuclei except the egg nucleus;[1] rarely, however, according to the same author, cells are engulfed bodily.[2]

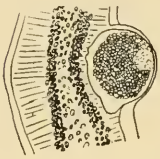


Fig. 3. Portion of manubrium of female medusa, with amoeboid egg, much enlarged.

My observations indicate a third process, namely, the incorporation of cells which have previously begun to disintegrate. They are in line here with the observations of Smallwood ('99) on the transformations occurring in cells adjacent to definitive ova in *P. tiarella*. I have found well-formed nuclei within the egg substance also; but have been unable to distinguish between cytoplasmic fusion and the bodily ingulfment of contiguous cells.

When full grown, the egg is from .25 to .30 mm. in diameter, broadly ovate when at rest, somewhat flattened, and opaque. A narrow, peripheral zone (ectosarc) is distinguished by the absence of yolk granules. The irregularities of outline (Figs. 3, 4) which are exhibited before the egg bursts through the attenuated layer of ectoderm investing the ovary, indicate amoeboid movements which are continued in unfertilized eggs often for many hours after they have been laid (Fig. 5). Maturation and fertilization were not observed. Those eggs, however, which, to judge by their normal development, had been fertilized, showed no more inclination to form pseudopodia than the blastomeres during the early cleavages.

Fig. 4. Manubrium of female medusa, with amoeboid eggs, just before laying. × 58.

Eggs were laid in the laboratory in May, June, July, August, September, December, January, and March, the only months in which observations were made; from which it seems probable that there is no circumscribed breeding season. They were

[1] Cf. Döflein ('96), for *Tubularia larynx*.

[2] Cf. Smallwood ('99), for *Pennaria tiarella*.

deposited at various periods of the day, usually during the early morning hours, many reaching maturity and being discharged at about the same time from the medusae of the same polyp They were heavier than sea-water and sank rapidly, clinging to any object they might touch. Occasionally they underwent several cleavages while adhering to the wall of manubrium or subumbrella, and frequently developed in contact with the base of the stem and the rootlets of the holdfast. Laid naked and in

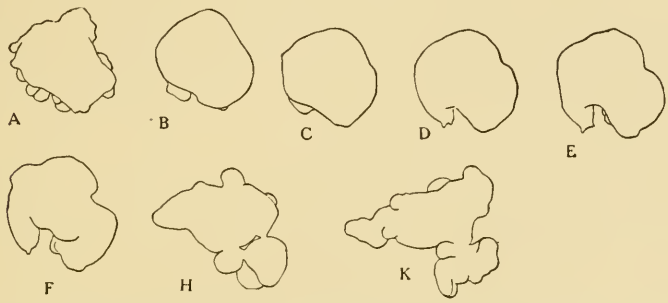


Fig. 5. Camera drawings of a single egg during forty-eight minutes. × 46.

large numbers, their amoeboid movements sometimes resulted in the fusion of two to fifteen or more into irregular amoeboid masses which failed to develop. Lots of eggs exhibiting the minimum number of fusions gave the maximum number of developments.

III. — Segmentation of the Egg; the Embryo.

For the purposes of this paper, the early development may be considered very briefly. The nucleus of the well grown ovarian egg is eccentric, lying next the thin ectodermic membrane investing the gonad (Fig. 3). Its position does not appear to have any future morphological significance for the individual. Fig. 6 represents typically the first four cleavages, beyond which point the behavior of individual blastomeres has not been followed. The first cleavage plane passes across the major axis of the egg, and results in equal blastomeres. The second plane passes at

right angles to the first, dividing each blastomere somewhat unequally. A small cavity between the blastomeres at this stage (Fig. 6, *F*) completely vanished a few minutes later (Fig. 6, *G*) The third cleavage first affects the two larger blastomeres; and the fourth may appear in the blastomeres thus formed before the two smaller cells of the four cell stage have divided.

Amoeboid processes are evident at different stages, but the egg as a whole retains a definite form to the close of segmentation. It is then approximately spherical, and is closely enveloped by a delicate chitinous membrane.

This stage is reached eight or ten hours after the egg is discharged from the parental manubrium. The embryo is then

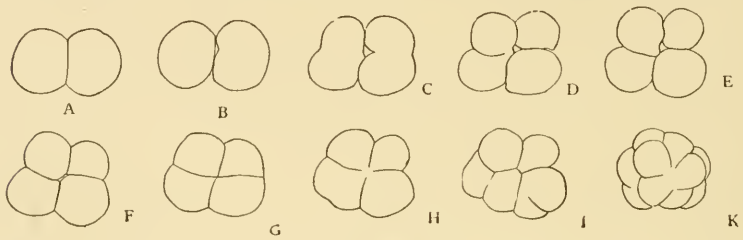


Fig. 6. Early cleavages of *Corymorpha* egg. Time, one hour. × 58.

composed of a solid mass of yolk cells surrounded by a layer of cells without yolk granules. Among the former, one or more cavities make their appearance. The peripheral yolk cells gradually assume an epithelial character. Within twenty-four hours, there is a single central cavity with epithelial walls which at first is almost filled by yolk cells in process of disintegration A columnar epithelial ectoderm is already extablished.

IV. — The Larva.

With the elongation of the body which now takes place, the embryonic period may be said to end and the larval period to begin. The latter presents certain peculiar features. The larva never passes through a free, ciliated, planula stage, but behaves from the beginning like a planula which has attached itself, lost its cilia and is on its way toward the formation of a polyp. The end which grows away from the substratum becomes the oral

extremity, as with the planula; the end which remains in contact with the substratum becomes the aboral extremity and in so far corresponds with the anterior end of the free planula.

1. *Locomotion.*—In leaving the chitinous egg capsule, the larva follows the course of the young growing stem. The wall at the point of exit is dissolved (Fig. 7), and the larva, as it emerges (Fig. 8), secretes a thin layer of perisarc which completely in-

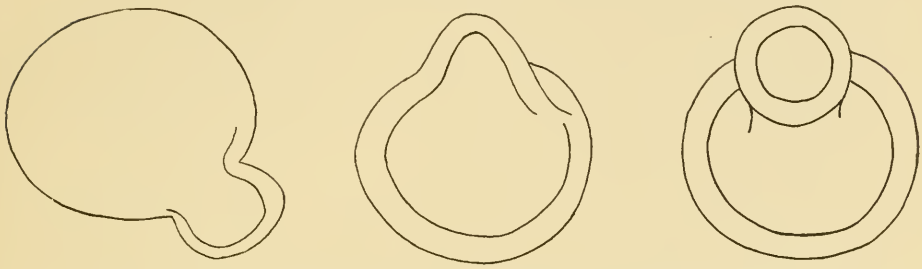


Fig. 7. Embryos emerging form the egg case, at different angles with the vertical. From above. × 116.

vests it and is continuous with the egg capsule. Unlike the ordinary growing stem, however, it exhibits a tendency for locomotion which is seen only under exceptional circumstances in permanently attached hydroids. Locomotion is accomplished by means of amoeboid cells in the ectoderm, and is always away from, never toward the egg capsule. A thin collapsed tube of perisarc is left behind.

Fig. 8. Embryo half out of egg case, enveloped in perisarc. × 116.

2. *Polarity.*—From the moment the larva begins to emerge from its egg capsule, oral end foremost, it may be said to possess a definite polarity. Elongation takes place along an axis which does not appear to coincide with the longer egg axis, nor with any other recognizable axis preexisting in the egg. If any such relation exists, it is probably readily obliterated by the reaction to

conditions obtaining during embryonic life. The adult stem changes its polarity readily when subjected to certain experimental conditions. Since the embryo and larva are morphologically far less specialized, they are presumably more plastic and capable of more facile transformations.[3]

The oral end of the polyp is determined by both internal and external factors. As has been indicated in a previous account of the locomotion of the larva (:04, p. 419), the latter early exhibits a marked negative geotropism combined with a negative thigmotropism. The simple expedient of rearing eggs on a plate inclined at an angle with the horizontal, was employed without positive results in the early stages. Yet it may be said that geotropism is exhibited by the time the tentacles begin to arise. As to thigmotropism, there is no doubt that the region of the egg which first emerges from the egg capsule is not in contact with the substratum, and never becomes attached to it in the future. In this respect, it behaves like the buds which develop on the free upper surfaces of the stolons in campanularian hydroids. Gravity does not appear to determine the point of emergence, because this point is only occasionally uppermost when the egg is resting on a horizontal surface (cf. Fig. 7). The processes which develop in contact with the substratum never develop into hydranths. It would appear, then, that the fate of any extension of the subspherical intracapsular embryo is fixed in part at least by its relation to the substratum. The emergence of any part is conditioned by its ability to dissolve the wall of the capsule. That in turn is a function of the ectoderm in all apical growing regions on stems or stolons. External factors do not seem to account for an accelerated growth of the embryo at any given point. That must then be referred to internal conditions of life which, from all obtainable evidence, are not constant in all individuals and do not suggest fixed polar relations in the egg or embryo previous

[3] In this connection, attention may be called to Perkins' (:02) description of the formation of buds on the larva of *Gonionema murbachi*. The distal end of the bud fastens to the substratum, instead of developing free, as in *Hydra*, *Cunina*, and many hybrids, and becomes the aboral instead of the oral end of the polyp. There appears to be more than an accidental correlation here between contact and differentiation.

to the establishment of the area of local accelerated growth. When the area of differentiation is established, however, it will only develop an oral extremity, provided it does not adhere to the substratum.

3. *Establishment of Body Regions. Elongation of Stem.*—After the larva has left the egg case, a somewhat swollen anterior region can be distinguished from a narrow posterior. At the anterior end the enteron is conspicuous (Fig. 9). Throughout the rest of the body, the endoderm is thicker than the ectoderm and is composed of large columnar cells which may almost obliterate the enteron. In twenty-five to thirty-five hours, the

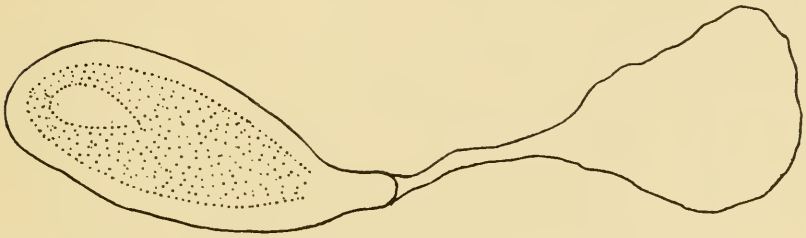


Fig. 9. Larva, with enlarged oral end, where enteron is seen.

larva has assumed the elongated form shown in Fig. 10. Accelerations and retardations in the development of the parts relatively to each other in different individuals lead to small variations in the development from this point.

By the end of the second day, the anterior region is further set off from the posterior by a slight constriction which appears about the middle of the body and fixes the limit between hydranth and stem (Fig. 11). In the ectoderm, the constriction is expressed by a shortening of the cells lying in its course, while, immediately below, the cells are at this stage occasionally lengthened to form a low annular thickening. The coelenteron narrows in the same region, owing partly to the constriction of the body, partly to a local increase in the prominence of the endoderm which serves to define the cavities of hydranth and stem.

A somewhat older larva is shown in Fig. 12, drawn from life, in two forms assumed within a few minutes of each other. The stem has lengthened. The hydranth is still completely invested

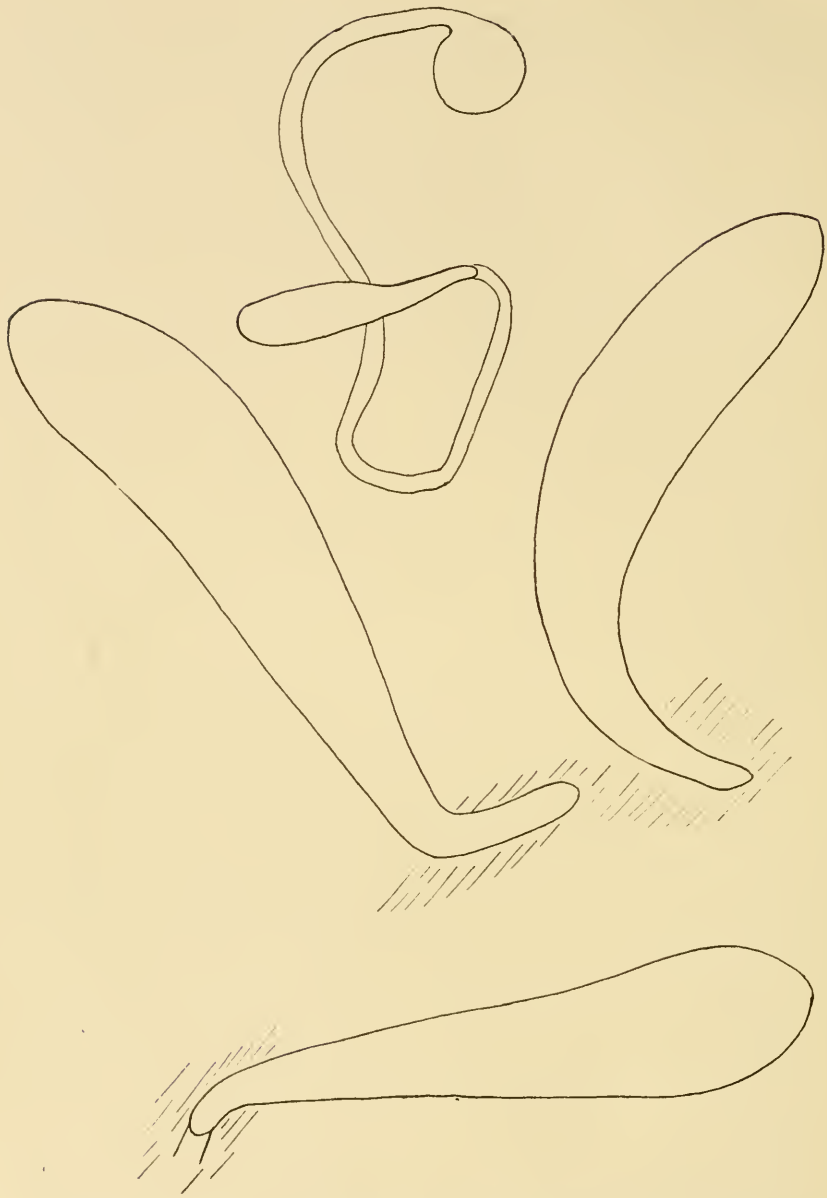


Fig. 10. A group of larvae from 25 to 35 hours old; much expanded, adhering to substratam by narrow posterior end only; no sign of hydranth. Uppermost figure (× 38) shows the aimless wandering of the larva from its egg case on a horizontal surface. Other figures × 116.

with perisarc, though tentacles are beginning to push out. Proximal tentacles appear at × in Fig. 12*b*. One distal tentacle appears at × in Fig. 12*a*. It is not often that both sets of tentacles begin their development so nearly at the same time. One to three, rarely four, distal tentacles usually make their appearance, as in Fig. 13, before any of the proximal set. In this figure, the stem is not so abruptly separated from the hydranth externally as in Fig. 12, but this is due mainly to the temporarily shortened and swollen condition of the stem. Internally, the endodermal ridge between the cavities of hydranth and stem is narrower, higher and more sharply defined than before; while the endoderm of the hydranth has lost the conspicuous yolk granules so characteristic of the earlier stages. The perisarc usually leaves the hydranth at this time, to be restricted hereafter to a portion of the stem whose upper limit is marked by the annular thickening in the ectoderm. The mouth is formed as the tentacles appear by a break through the thin apical region of the hydranth, and at the stage represented in Fig. 26*a*, numerous gland cells are present in the endoderm in its vicinity.

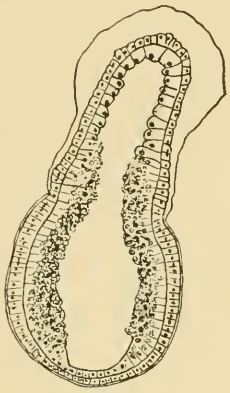


Fig. 11. Optical section of larva in which hydranth and stem are distinguishable. × 135.

I wish to call attention here to the significant fact that there is no important increase in the length of the larva until the endoderm cells begin to vacuolate and increase in size by the absorption of water; further, that the most rapid increase takes place in the stem, where the cells are largest and most highly vacuolated. Such a correlation between elongation and absorption of water can hardly be ascribed to accident. It suggests strongly a mechanical morphogenic factor which may be discussed more conveniently and fully in connection with the experimental evidence for form-changes in regenerating stems. The subject will be treated, then, in the third paper of this series.

V. — Development of the Tentacles.

The development of the tentacles, with the typical irregularities, is illustrated in the accompanying nine series of diagrams

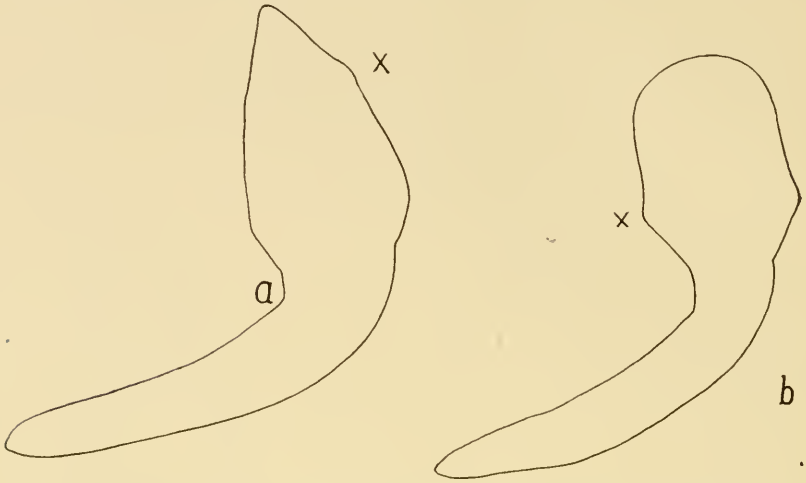


Fig. 12. Two views of the same larva, from life, showing the clear separation of stem and hydranth, and the beginnings of tentacles.

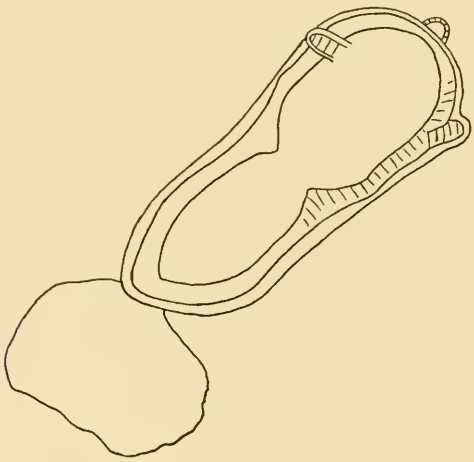


Fig. 13. Larva with 3 distal tentacles showing endodermal ridge between cavities of hydranth and stem. × 135.

(Fig. 14). The numerals indicate order of appearance, Arabic standing for distal, Roman for proximal tentacles. The dia-

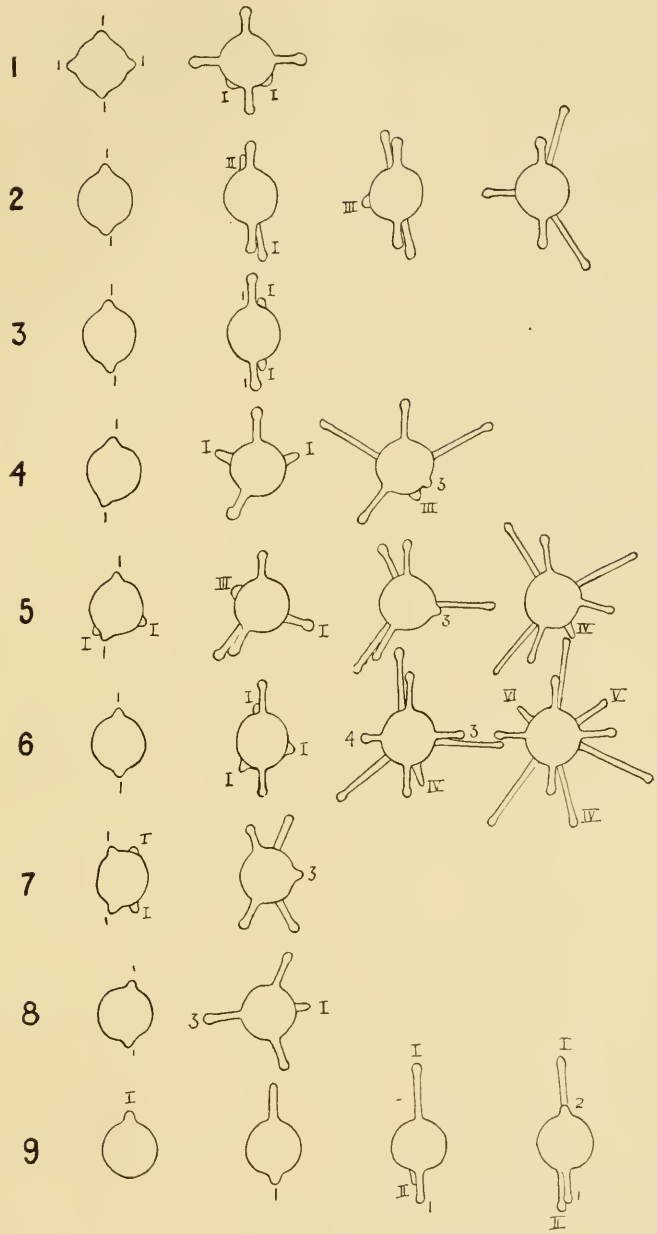


Fig. 14. Nine typical series, illustrating the appearance of distal and proximal tentacles. From above. Semi-diagrammatic.

grams show that the distal tentacles tend to appear before the proximal. The first two arise simultaneously and opposite or nearly so in ten among thirteen cases (77 per cent.); the first four may arise simultaneously, as in (1); occasionally the proximal set may begin before the distal, as in (9). The members of the proximal set have no definite position relatively to the members of the distal set of corresponding age, although, as in (2) and (3), they may sometimes arise in the same plane. The first two proximal tentacles are opposed in four among fourteen cases (28.5 per cent.), showing a less tendency to regularity than the distal tentacles.

The following is a tabulation of the number of tentacles in distal and proximal sets in fifty-five individuals whose development in most instances was not observed.

Dist.	Prox.	No. Ind.
0	2	1
2	0	4
3	2	2
3	3	1
3	4	1
3	5	1
3	6	2
3	7	1
4	0	1
4	6	8
4	7	7
4	8	2
5	5	1
5	6	1
5	7	5
5	8	6
5	9	2
6	8	2
6	12	1
7	12	2
12	11	1
15	15	1
15	16	1
17	15	1
	Total,	55

The diagrams and this table, taken together, show that while distal tentacles appear, on the whole, earlier than the proximal,

they do not multiply so rapidly in the beginning; that when they reach the number of four there is a pause in their development, during which the proximal tentacles continue to increase in number without any delay; that by the time the proximal set attains to little more than half its total number, the distal set contains an equal number. From this point the distal set continues to increase more rapidly than the proximal, and ultimately contains twice as many tentacles as the latter.

The pause after the appearance of the fourth distal tentacle seems to indicate that the development is according to a quartette plan. Other facts suggest the same conclusion; for instance, the third and fourth tentacles appear almost invariably in the same positions relatively to the other two, that is, in regular rotation. The numerical increase of the distal tentacles has not been followed beyond this stage.

There is nothing in the rhythm of the development of the proximal tentacles to indicate quartettes. In serial diagrams (5) and (6), however, the typical facts are represented that IIIpr. arises as far away as possible from Ipr. and IIpr., while IVpr. arises opposite IIIpr.; which suggest either a primitive quartette formation that has been secondarily obscured, or a dependence of the quartette arrangement upon mechanical factors.

The asymmetrical relation of the first two distal tentacles in serial diagrams (4), (5) and (7) seems to find an explanation in the assumption that they are slightly displaced in advance of the appearance of 3d. With the appearance of 4d., they become strictly opposite, as in (6). Each succeeding tentacle tends to occupy a position in the widest available interval between any two contiguous tentacles. This statement is well born out by the proximal tentacles, a typical development being shown in (6). IVpr. appears in the widest unoccupied space; Vpr. appears without pause, as nearly opposite as possible, never contiguous, in the next widest unoccupied space; VIpr. follows the same rule. The tentacles may follow, in the order of their appearance, the rotation of clock hands or the reverse. In either case, the facts prompt the view that space considerations materially assist in determining the type of tentacular development.

The early development of the individual tentacles, whether proximal or distal, includes the same series of changes in all, with the one exception that in the latter a slight thickening of the ectoderm may precede evagination. Noting this exception, it will not be necessary to describe the course of the development in each set. I have selected as typical of both the development of the proximal tentacle.

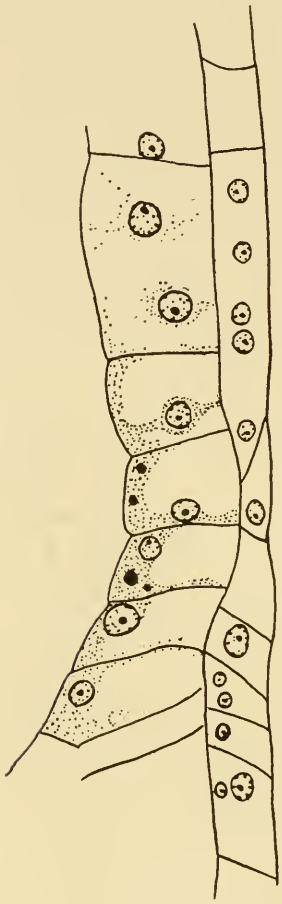


Fig. 15. Early stage of proximal tentacle. Optical section. × 910.

The first changes which I have been able to discover in the origin of a proximal tentacle involve both endoderm and ectoderm. At the point where the tentacle is to appear, near the base of the hydranth, from seven to ten epithelial cells, belonging to the lining of the hydranth cavity, exhibit certain peculiar characters: they are smaller and richer in protoplasm, which may account for their slightly deeper tint when stained with haematoxylin (Fig. 15). I have been unable to determine their origin definitely, except in so far as to be satisfied that they do not spring from *interstitial* cells. They are either directly transformed functional epithelial cells, or products of the division of a few of the latter. In the absence of mitotic figures, both hypotheses might be assumed to be true. The number of divisions at this stage could at most have been very limited, and might be interpreted as the beginning of the series of divisions which undoubtedly occur in the axial cells of the tentacle after they have been

separated from the epithelium of the hydranth cavity. Whatever our assumptions regarding the few small deeply staining cells in question, there is no doubt that they furnish several cells to the axial endoderm of the tentacle, by a process which would seem to come into the category of morphallactic phenomena.

An evagination of that area of the endoderm occupied by the small cells accompanies their appearance. At first it produces no external effect, for the layer of continuous ectoderm external

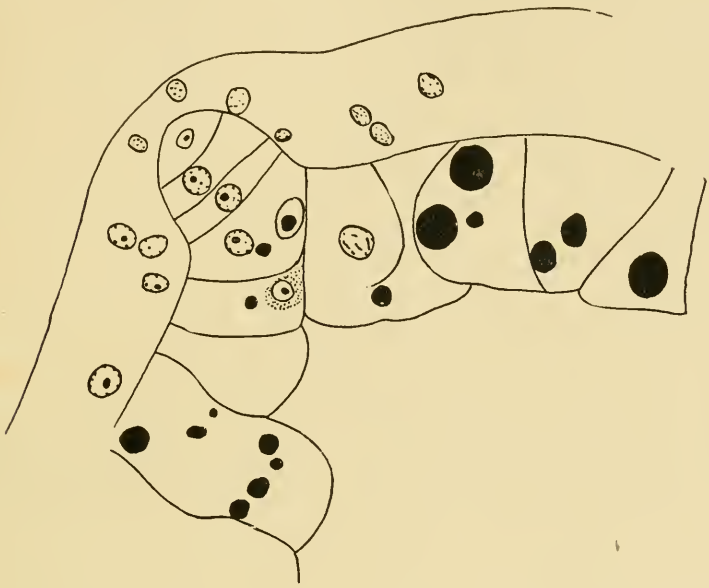


Fig. 16. Longitudinal section cut through a developing proximal tentacle. × 910.

to it thins out as it advances, apparently because it advances, the endoderm leading the way. The ectoderm cells on either side of the thin area next increase in number, forming a somewhat thickened ring about the growing tentacular axis. The latter, carrying the thin layer of mesogloea with it, is pushed out as a single column of cells from the endodermic evagination (Fig. 16).

A number of cells varying from four to ten are thus incorporated in the developing tentacle. The positions of the cells

in the longitudinal section of the tentacle represented in Fig. 16 support the view that an incorporation of epithelial cells actually takes place. The presence in the tentacular endoderm of deeply staining granules (Figs. 16 and 17) which, both before

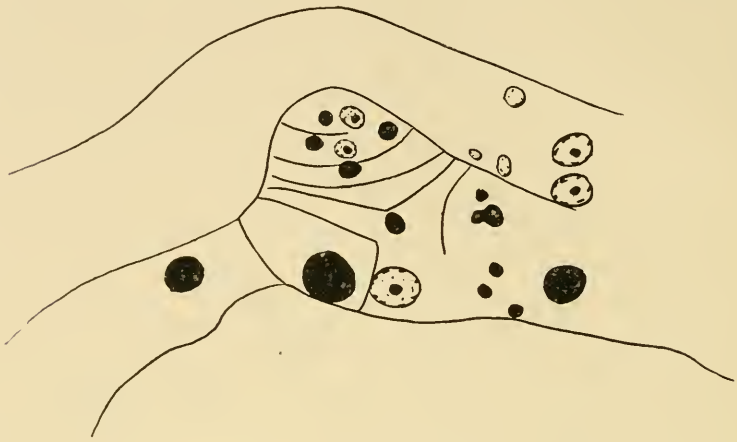


Fig. 17. Section through a developing proximal tentacle; very slightly oblique. × 960.

and at a slightly later stage are limited exclusively to the hydranth epithelium, points in the same direction. When the axial endoderm of the tentacle possesses about ten cells, some derived bodily from the hydranth epithelium, others possibly products of intratentacular divisions, it is sharply set off from the epithelium by the establishment of a delicate layer of intervening mesogloea (Fig. 18).

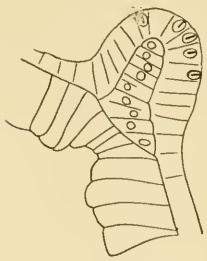


Fig. 18. Optical section, developing distal tentacle. × 175.

The tentacles, in their development up to this point, may be said to incorporate elements from both ectoderm and endoderm. These elements are similar to each other in either layer. The gland cells are absent which appear in the endoderm when the mouth is established and the animal is prepared to ingest new food materials. Nettle cells, the most conspicuously differen-

tiated cells of the ectoderm, do not show themselves until the tentacle anlage has become clearly delineated. Both endoderm and ectoderm cells are smaller, lower and relatively broader than in the adult. The larval endoderm and ectoderm, then, which contribute to the formation of the original tentacles of the polyp are much less specialized than the mature tissues which may be present in the regenerating zone of an adult.

The further development of the tentacles involves special histological changes in the tissues now already established. The proximal tentacles elongate much more rapidly than the distal. Both acquire very early a number of nematocysts in the terminal ectoderm (Fig. 18) which soon thickens into a knob. The knobs are recognizable on the distal tentacles even after sixteen proximal tentacles—more than one-half the total number—have appeared, and when six to eight of the characteristic peripheral canals of the adult have been fashioned out of the primitive enteron. At this stage the proximal tentacles have lost completely their capitate tips, which were present when they numbered eight.

With the increasing size of the tentacles, the cells of the tentacular endoderm alter their shape. Originally placed one upon another in a single row after the manner of a roll of coins and in accord with their arrangement in the vast majority of hydroids, which have smaller tentacles than *Corymorpha*, the axial cells retain this arrangement in polyps with eight to ten proximal tentacles. In one polyp with six distal and twelve proximal tentacles, the former have but one row of cells throughout, while in the latter there are two rows in the middle third and three rows in the basal third. In larger polyps, with fourteen to sixteen proximal tentacles, the axial cells have abandoned the simple arrangement in the basal halves of both proximal and distal tentacles. At this stage, there are two rows of axial cells in the basal half of each distal tentacle. These rows dovetail slightly, each cell covering a little more than half the cross section of the endodermic axis, with its longest diameter horizontal.[4] The basal halves of the proximal tentacles contain at this time about

[4] That is, parallel with the transverse diameter of the vertical polyp.

six rows of axial cells, not placed with perfect regularity in linear series, yet the longest diameters of all horizontal, parallel with each other and with the longest diameters of the corresponding cells in the distal tentacles. In the full grown adult there may be four rows of axial cells in the basal region of each distal tentacle, ten in the greater part of the length of each proximal tentacle. Both kinds of tentacles have narrow, filiform ends, where the cells retain their original arrangement in a single row.

The horizontal orientation of the elongated axial cells in the adult bears a definite relation to the movements of the tentacles. The latter move characteristically inward and outward (up and down), never toward one side. The longest axis of each axial cell is therefore always perpendicular to the plane in which its tentacle moves. This condition is obviously well adapted mechanically to the direction of the movements. Since the latter occur in the same planes from the time of the origin of the tentacles throughout the life of the individual, the inference is readily suggested that the movements of the tentacles may actually determine the arrangement of the axial cells. Whatever displacements of cells might be caused by the movements of a tentacle would naturally take place in the plane of the movements.

It seems probable, therefore, that not only may the number of axial cells in any cross section be conditioned by the size of the tentacle at that point, but their arrangement may be conditioned by the direction of the tentacular movements.

VI. — Development of the Frustules.

The root filaments or "frustules" (Allman) are produced throughout the life of the polyp. They arise early in the development, occasionally before any of the tentacles. At first there is a tendency to scatter. They are rarely terminal, though they are usually restricted to the proximal half of the stem. They may appear singly, or by twos and threes, but only exceptionally at the same level. They do not appear in response to a contact stimulus, arising on all sides of a stem, whether it be resting on

the bottom or suspended freely in the aquarium; but they do not grow to their usual length, and their ends retain a cylindrical shape, unless they come in contact with the substratum, which provides the mechanical aid necessary for their later development.

In the adult the frustules occupy a definite zone about one sixth the length of the stem from the proximal end, arranged in from two to four vertical rows on each peripheral canal. They become progressively older proximally.

The origin of the frustules does not differ essentially in larva

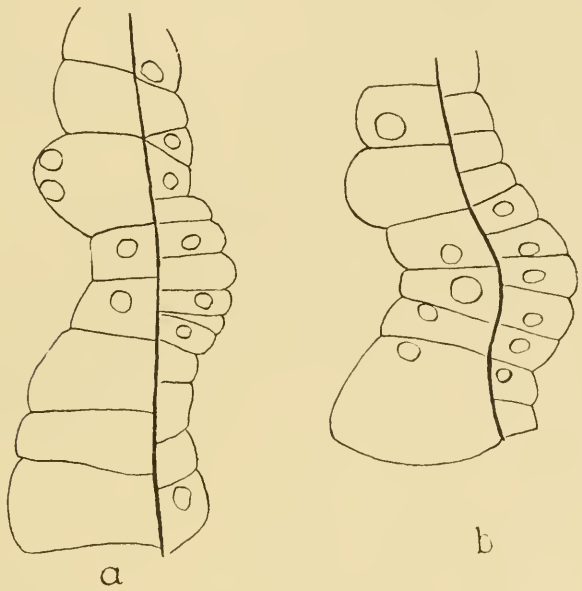


Fig. 19. Two optical sections of same developing frustule from larva with six proximal tentacles. × 1210.

and adult. In both the body wall evaginates and epithelial endoderm cells are incorporated as a portion of the axial tissue, in which a cavity is wanting from the beginning. In so far the development closely parallels the development of the tentacles. There is also a preliminary change in the ectoderm to be evaginated, which in the larva is almost identical with the thickening of the ectoderm where the distal tentacle is to appear.

Fig. 19 presents two optical sections of the same frustular anlage from a larva with six proximal tentacles. The increase in number and depth of stain and the decrease in size of the endoderm cells, which were characteristic of the development of

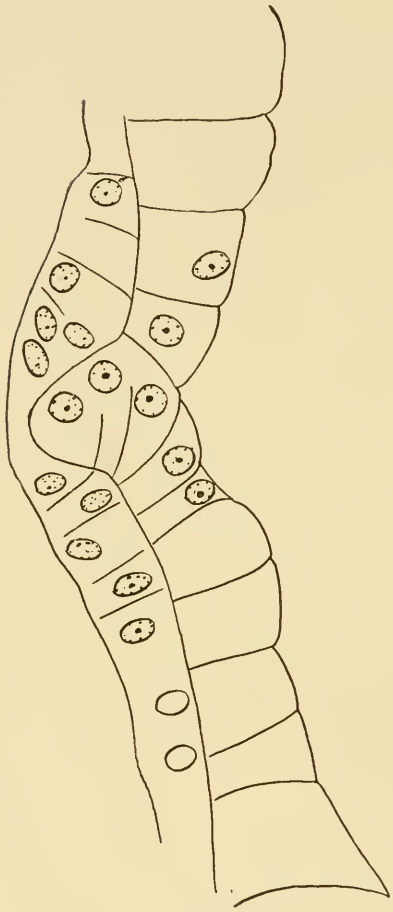


FIG. 20.

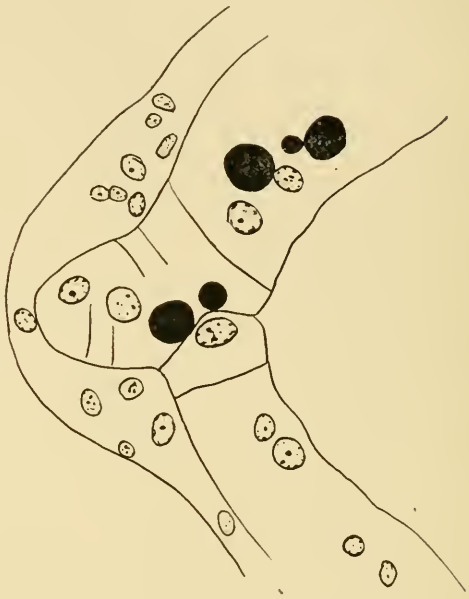


FIG. 21.

Fig. 20. Longitudinal section through a developing frustule. × 910.
Fig. 21. Section across stem, through base of developing frustule, showing connection between frustular and enteric endoderm. × 910.

the tentacles, are found here. The ectoderm cells above this modified endoderm are more deeply stained, higher and more

numerous than elsewhere. The causes suggested for the changes in the endoderm of the tentacle anlage will apply equally well here. Fig. 19*b* is a median section showing the beginning of the evagination. The subsequent course of events involves, first, the emigration of several cells in a single row, which push out the ectoderm and thin it before them.

The resemblance of a frustule at this stage (Figs. 20, 21) to a proximal tentacle (Fig. 16) is remarkably striking, especially when it is remembered that the fate of the two as well as their origin in the history of the race are so different. Similar mechanical problems appear to be meeting with similar mechanical solutions.

The frustule soon turns downward and, running close along the column, gradually lengthens. Its tip becomes clavate, terminating a more and more attenuated stalk. Just how many cells enter it from the enteric epithelium it is impossible to say. Mitotic figures are again absent, and though the rod of frustular endoderm becomes exceedingly narrow and delicate at its base, a direct connection with the endoderm of the column can be demonstrated at a stage much later than that in which the tentacular endoderm is separated from parent epithelium by the mesogloea. A definite delimiting layer of mesogloea is probably never developed, though it is also quite probable that the endodermic epithelium does not contribute cells throughout the period during which the frustule elongates. It is certain, as will be seen below, that the elongation of the frustule is not wholly dependent upon an increase in number of axial cells, from whatever source they may come.

In the adult the first visible change noted in the development of a frustule is an increased granulation of the ectoderm cells in a small circular area over a peripheral canal. The granules stain conspicuously with both haematoxylin and orange G. At the same time, as can be seen in sections of the stem, the granular cytoplasm of the endoderm cells under this area stains more deeply with haematoxylin, a change evidently correlated with a simultaneous thinning of the mesogloea from the *inner* surface. The ectoderm cells take on a higher, narrower, columnar form.

The endoderm cells become smaller and more numerous. Fig. 22 shows the beginning of evagination of both endoderm and ectoderm. The layer of endodermic muscle fibres is interrupted where the epithelial cells push outward in the shape of a solid rod. At the same point, the mesogloea thins out and arches outward, accompanied by the ectoderm. The latter soon diminishes perceptibly in thickness with the shortening and broadening of its columnar cells (Fig. 23). The endoderm meanwhile arranges itself in the single row of cells characteristic of the well developed frustule, and pushes through the original mesogloea. These points are shown in Figs. 23 and 24; the latter is very slightly oblique but does not distort the facts, at the same time exhibiting the derivation of frustular axial cells from enteric epithelium.

Fig. 22. Early stage in development of frustule on adult stem. × 360.

The frustule next develops a thick, slightly bulbous base and a narrowed extremity, its axial cells continuing to show conspicuously the green granules so characteristic of the epithelium from which they came. In the course of further development the base narrows until, in a fully developed filament, it is almost impossible to distinguish where it joins the stem. Finally, the filament degenerates, having created a perisareal anchor for the stem.

Fig. 25 shows that the extent of the granular ectoderm, which is the first indication of the frustule from a surface view, increases up to the time when the ectoderm of the frustule begins to thin at the tip, and then gradually decreases as the ectoderm of the frustule thins out progressively toward the base. In all probability this means that many ectoderm cells are being transferred from column to frustule, there to be modified in form in accordance with the lateral tension under which they appear to be placed by the elongation of the axial rod.

After extending slowly down the column for a varying period of days, under the perisarc, the frustule develops a clavate tip and dissolves a passage through the latter by means of the cells with which the ectoderm is now furnished. The clavate end is capable of secreting perisarc also. It behaves in these respects

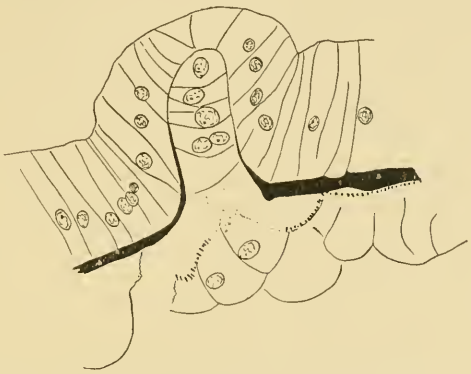


Fig. 23. Longitudinal section through developing frustule of adult. Endoderm ruptured at base of frustule.

like the end of a stolon, and in one other: it is amoeboid. I have described elsewhere its locomotion,[5] which has an intimate bearing on the future form of the organ. The stimulus of contact, though in no sense a cause of the origin of the frustules, is an

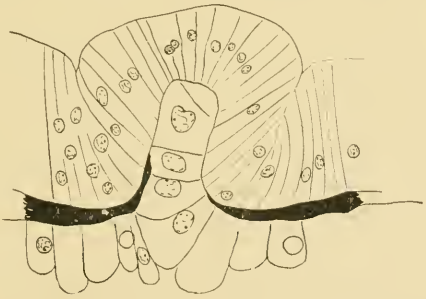


Fig. 24. Section similar to last, very slightly oblique.

important factor in their development. Their club-shaped ends flatten when they reach a substratum and suddenly begin active creeping movements which have been observed to carry them

[5] Journal of Experimental Zoology, I, p. 416.

along at the rate of 15 mm. a day. This rapid locomotion is accompanied by a rapid elongation of the frustule into an attenuated filament. The elements of the structure are put upon the stretch. Its ectoderm may become so thin as to be readily overlooked. The cells of the endodermic axis, instead of remaining short and broad, become relatively long and narrow. There is no doubt that a considerable proportion of the entire length of the filament is a direct result of the tension created by the locomotion of the amoeboid end. A setting process which accompanies the stretching provides against a return of the filament to its earlier form. The morphological change, mechanically induced, has a certain permanence.

Fig. 25. Series of frustules developing on canal of adult stem; surface view.

So rapid is the development of the filament, once the end is in contact with the substratum, so pronounced the effect upon the forms of both endoderm and ectoderm cells, and so narrow and delicate the connection with the stem, that there is little doubt that a functional connection with the latter is lost before the filament actually breaks away. Both physiologically and from the standpoint of the polyp, the end of the filament is the important part of it. It secretes a perisarcal anchoring filament. Whether it do this while attached to or disconnected from the stem appears to be immaterial for short spaces of time. It may travel forward independently for several hours. In this condition, however, there is no evidence that it will ever transform into a larva.

In this condition, however, there is no evidence that it will ever transform into a larva.

VII. — Metamorphosis.

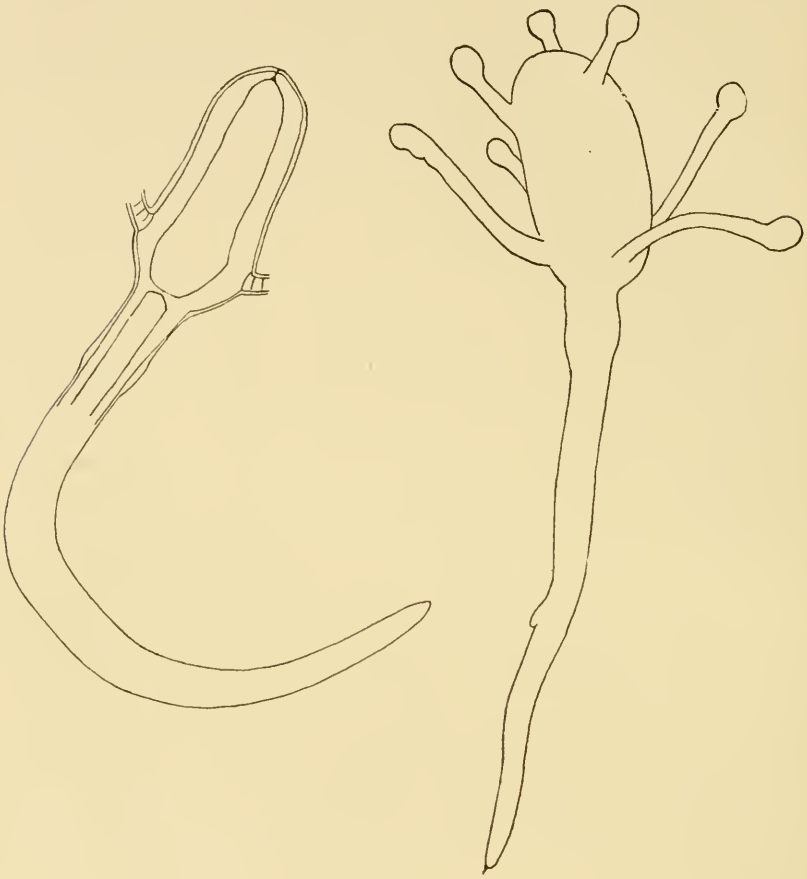
Aside from the development of the tentacles and frustules, the polyp reaches its adult condition by a transformation so

pronounced that the term metamorphosis may well be applied to it. The single central cavity of the larval stem is rapidly reduced to a series of small peripheral canals by the establishment of a central rod of immense, vacuolated skeletal cells. The stem, at the beginning about as long as the hydranth, increases in length until it may become ten times as long as the latter, whose cavity meanwhile is divided by a large cushion of vacuolated endoderm cells into pre- and post-tentacular portions. Finally the perisarc is pushed back until it covers no more than the proximal third or fourth of the stem. In structure and proportions, then, larva and adult are strikingly different, a fact to which we shall return in the later consideration of the problems of regenerative development.

1. *Recession of the Perisarc.*—The external changes may be considered first. The beginning of the annular ectodermal thickening which finally marks the oral limit of the perisarc is shown in Fig. 11, being the result of an increase in length of the cells in its course. It is here close behind the constriction which marks externally the aboral limit of the hydranth. As yet the perisarc envelopes the whole individual. In Fig. 26, an optical section of a polyp with four distal and six proximal tentacles, the thickening has broadened and shifted backward a distance nearly one-half the length of the hydranth. It is now the oral boundary of the perisarc. The section represented by Fig. 27 is through a polyp with five or six peripheral canals. It shows that the thickening, which maintains about the same relative position, has changed its character. Fig. 28 is a detail of the zone of transition between the ectoderm above and below the perisarc, showing that the thickening is still due to the elongation of ectoderm cells. The naked ectoderm exhibits a new tendency to roll over the edge of the perisarc; this becomes more pronounced with age. The cells beneath the perisarc stain more deeply and wear the aspect of gland cells. In both naked and covered ectoderm, nematocysts develop, but much more abundantly in the former.

From this time the perisarc recedes gradually to its adult position. The change is due partly to the general elongation of

the stem, which is more rapid than the elongation of the hydranth. Such a factor, however, does not explain how the naked ectoderm, which occupies one-eighth the length of the stem at the stage shown in Fig. 27, comes to occupy, in contraction,



a *b*

Fig. 26. *a,* Optical section of larva with six proximal tentacles. Stumps of two tentacles shown. × 120. *b,* larva with three distal and four proximal tentacles.

more than half the length of the stem in the full grown adult. This extension of the naked area may be due in a small measure to the more rapid growth of this portion of the stem; I have no

evidence for it. The main reason for the change is with little doubt the transformation of the covered ectoderm cells progressively toward the base of the stem. Such a view is supported, first, by the close approximation of the edge of naked ectoderm to the zone of frustules which remains at its original proportional distance from the basal end; second, by the ready transformation of covered ectoderm cells into the naked type during the regeneration of the hydranth in the region of transition, a

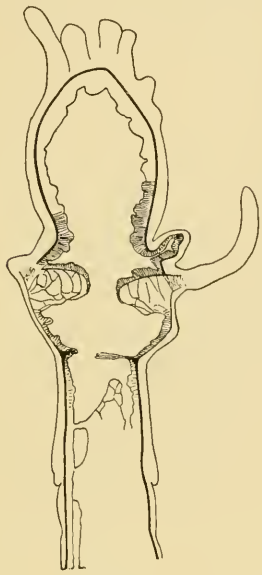


Fig. 27.

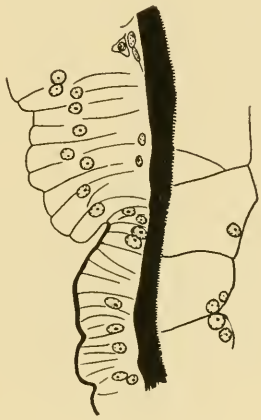


Fig. 28.

Fig. 27. Longitudinal section of polyp with five or six peripheral canals. × 42.

Fig. 28. Section to show transition between naked and covered ectoderm of body wall. × 460.

fact which will be illustrated in the third paper of the present series.

2. *Development of Axial Parenchyma.*—The most profound change accompanying the transformation of the larva into the adult is to be observed in the establishment of the axial rod of turgid endoderm cells and the appearance of the peripheral canals. It is accompanied by the development of a fenestrated

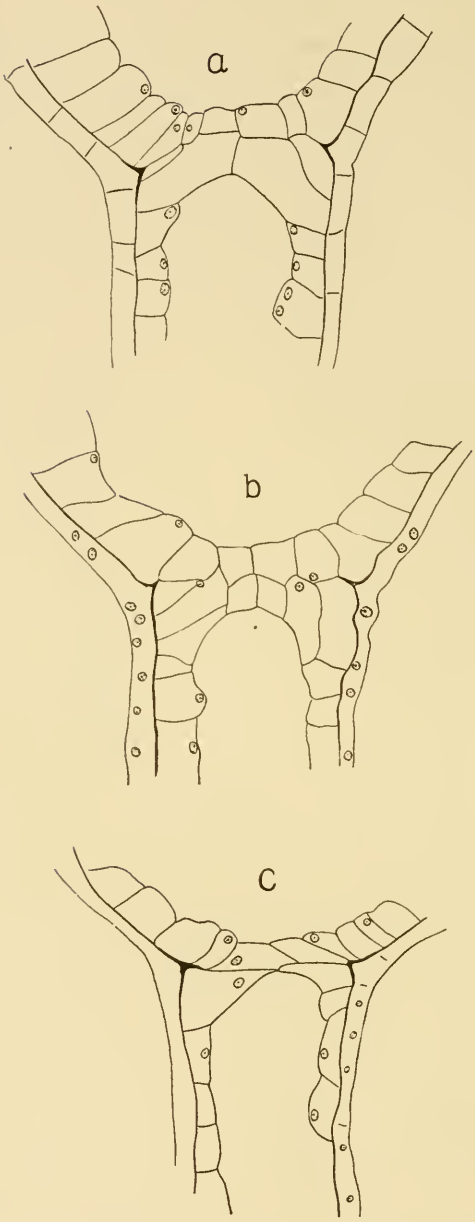


Fig. 29. Longitudinal optical sections of larvae through bridging parenchyma at base of hydranth. *a, b,* Through same polyp; *c,* through another polyp with attenuating membrane. × 230.

membrane between hydranth and stem from the annular thickening of the endoderm in that region.

(*a*) *The fenestrated membrane* begins to develop in advance of the peripheral canals. It has been noticed already in Figs. 11 and 13, where it is composed of a ridge of columnar cells which have become longer than their neighbors. Fig. 26*a* shows a slightly later condition, which is detailed in Fig. 29. Fig. 29*a* and *b* represent longitudinal optical sections through a polyp with four distal and seven proximal tentacles. Fig. 29*c* is a similar section through another polyp of the same age. The projecting ridge has fused from all sides across the enteron in each case, forming a partition between hydranth and stem cavities with a trifling intrusion of mesogloea at its outer edge. In Fig. 27 the partition has thinned out into a membrane with fenestrae, one of which is shown in the section. The mesogloeal intrusion has increased into a narrow shelf. Fig. 30 represents a cross section, through the membrane, of a polyp of about the same age, in which five to eight canals are developing and fourteen proximal tentacles are present. The outermost white zone is ectoderm. The adjacent broad zone with concentric striations is the horizontal shelf of mesogloea on which lies a thin layer of fibrils which are by no means so conspicuous as the figure indicates. The central area is occupied by a thin membrane, pierced by nine irregular fenestrae and composed of numerous small non-vacuolated cells with their longest diameters approximately radial. The fenestrae correspond with eight canals that are taking shape just below in the stem.

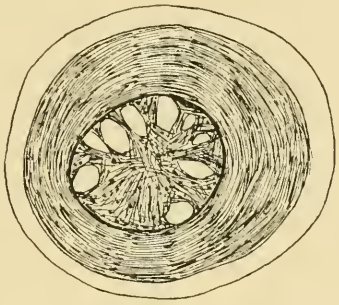


Fig. 30. A composite of two contiguous transverse sections of a young polyp, passing through the fenestrated membrane.

An attempt to explain the formation of the fenestrated membrane naturally recalls the formation of the membrane across the open end of a wounded *Tubularia* stem. Though the latter

involves both ectoderm and endoderm, there is the same attenuation of cells that is shown in Fig. 27. Morgan (:02) thinks "it very probable that the closing process involves an amoeboid-like extension of the coenosarc across the open end." The closure of wounds in *Corymorpha* will be considered later and a comparison will be made then with the phenomena in *Tubularia.*

The construction of the fenestrated membrane in *Corymorpha* appears to involve: (1) a local increase in the size (expressed mainly in length) of endoderm cells in a narrow annular zone (Fig. 13), the cells being closely pressed together and fusing laterally; (2) a fusion of the cells by their inner ends (Fig. 29, *a* and *c*), accompanied by a cessation of their growth; (3) an expansion of the stem in the same region, with a resulting strain upon the partition (Fig. 29*c*); (4) as a result of the strain, the attenuation of the partition cells (Figs. 29 and 31); (5) proliferation of membrane cells; (6) formation of fenestrae These events will be considered in their order.

(1) The increase in size of the bridging cells is a result of an absorption of water. As the bridging cells lengthen the quantity of their protoplasm remains practically constant, while their vacuoles enlarge. Water is evidently being absorbed. The first result of the absorption of water is an increase in turgidity with a consequent increase in size of the cells. What form the enlarging cells may take seems to be determined in this case by the pressure of contiguous cells and by mutual adhesion. The only necessary factors in the elongation of the endoderm cells in preparation for the formation of the membrane seem to me to be growth (increase in volume) and intercellular adhesion. Whether the rather obscure amoeboid activity which Morgan has suggested in explanation of the closure of cut ends in *Tubularia* stems occurs or not—which cannot be determined in the absence of observations on live animals—it does not appear to be necessary at all in accounting for the results here. The preparations from which this conclusion is drawn are in entire harmony with it.

(2) The bridging cells cease to grow, according to measurements, at about the time of their fusion across the enteron. Consequently, (3 and 4) any increase in the diameter of the column at their level thereafter must subject them to a tension, which might be relieved by cell multiplication, attenuation of the bridging cells or the dislocation of some of the adjoining epithelial cells which might be carried out into the bridge. The facts indicate that all three methods occur. The behavior of the mesogloea in Fig. 29 shows that even thus early the cells on the thickened ridge are tugging at their basal ends, carrying the mesogloea out into the bridge, and arranging themselves into a double layer upon it, suggesting a slight evagination which is not pushed out but pulled out. That attenuation of the bridging cells under tension may take place is shown in polyps of the

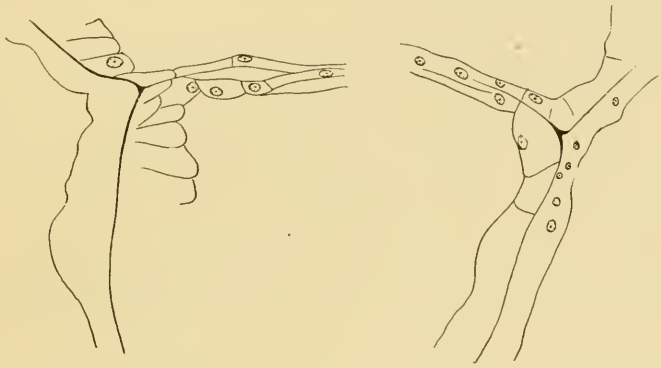


Fig. 31. Longitudinal section through a polyp of same age as those shown in Fig. 29; bridge between cavities of hydranth and stem attenuated into membrane, which shows a rupture. × 460.

same age as those represented in Fig. 29 whose diameters have been augmented by internal or external pressure. Fig. 31 represents the partition in such a polyp, which has increased its diameter because it is under strong longitudinal contraction. Making allowance for the break which occurred during the course of preparation, the diameter of the column at the level of the partition is almost twice as great as in Fig. 29. And as the bridge or partition has lengthened it has decreased proportionately in thickness.

Contraction of the stem does not appear to be the only method of increasing its diameter and producing a tension on the membrane. It is noticeable in the figures in Fig. 29 that there is an upward arching of the partition. The latter at this stage is an unbroken sheet of cells completely separating the cavities of hydranth and stem. The cavity of the stem, then, has no outlet. Under this condition, a rise in osmotic pressure of the liquid filling it would distend its walls wherever possible. The non-muscular parenchymatous partition would be forced outward and its cells put upon the stretch. The degree of outward displacement would depend partly upon the pressure in the hydranth cavity. The tension on the membrane, however, would not be affected by that fact, provided the walls of the stem were not rigid, non-extensible at the level of the partition; and they are not rigid, as we have seen.

In the larval stages of development, the same pressure may be a considerable factor in the elongation of the stem. There is evidence that it exists even after the peripheral canals have become well established; but at that time it can have little effect upon the form of the stem in comparison with the turgid axial endoderm to be considered below.

(5) It is hardly to be questioned that the cells in the membrane, once it be established, add to their numbers just as the other structures in the body do, by proliferation. There is no evidence, however, that cell division plays an active part in the extension of the membrane.

(6) The fenestrae develop irregularly between the cells of the membrane in connection with the peripheral canals. They are not present from the beginning, the membrane being unbroken even when the polyp possesses nine proximal tentacles, a mouth and a well differentiated digestive epithelium in the hydranth. It is suggestive that they appear at the points where the corresponding peripheral canals, with outer walls of ciliated cells, could deliver columns of water against the membrane.

(*b*) *The development of the peripheral canals* may now be traced. Fig. 32 represents a section from the middle stem region of the same polyp whose fenestrated membrane is shown in

Fig. 30. The striking feature of it is the differentiation of the endodermal epithelium. There are four regions in which the epithelium is normal or approximately so, and four intervening regions in which certain cells have increased enormously in bulk and met across the enteric cavity, dividing it into four parts (A–D). These openings vary in area. Two of them (C and D) are much larger than the others and show signs of further division that demonstrate the method by which the original four openings were formed. The epithelium bounding C and D on

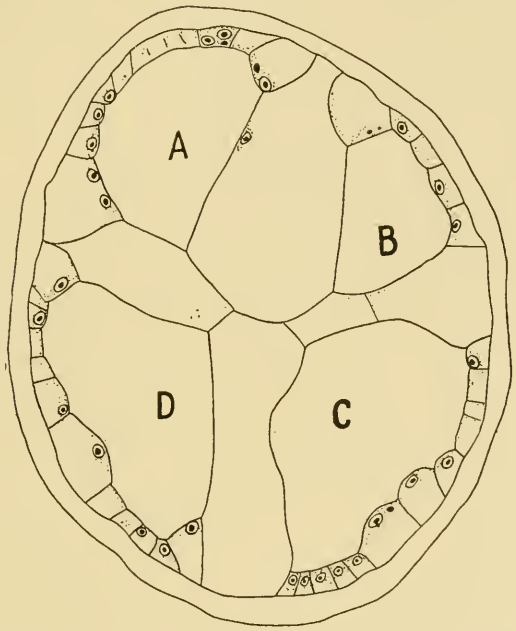


Fig. 32. Transverse section of young stem, showing formation of canals (A, B, C, D) and axial parenchyma. × 280.

the outside is divided in each case into two lateral groups of normal cells and a median group of two or three cells which have begun to absorb water and bulge out into the canal. These median groups represent the beginnings of more partitions like those which separate A and C from B and D. One of the cells in each will swell until it reaches and fuses with the vacuolated cells which have already united in the center. Other divisions

and subdivisions will be made until the adult condition is attained, when 17 to 20 peripheral spaces may be seen.

The spaces are sections of longitudinal canals. The endodermal cells which separate them in Fig. 32 belong to epithelial ridges extending more or less completely the length of the stem. The height of the ridge cells may vary much, however, even in contiguous sections, as a consequence of which the number of canals visible in different sections of the same stem at this stage may vary irregularly. One large canal may, in the course of a few sections, be divided into two, and at the same time the ridge separating two others may lower abruptly and afford a means of communication between them. Such gaps are usually filled up in the adult, where the peripheral canals are regularly longitudinal, only occasionally branching or laterally in communication.

In general it may be said that the canals appear first near the hydranth, in connection with the fenestrated membrane, decreasing in number proximally.

When the enteric cavity begins to fashion itself into peripheral canals owing to the intrusion of vacuolated epithelial cells from longitudinal ridges, the intruding cells swell out singly from the epithelial layer. As single cells, also, with their bases on the mural mesogloea, they join in the median line, by means of their inner ends, the corresponding cells from other ridges. Fig. 32 illustrates both of these statements. At this stage, the two essential characters of the adult stem are recognizable: (1) several canals instead of one, their external walls of low epithelium and bounded internally by immense vacuolated cells which separate them from each other; (2) an axis of vacuolated cells occupying the center of the original enteric cavity.

In the further development of the stem, the canals grow more numerous and the axis of vacuolated cells increases in importance, the canals retaining a subordinate peripheral position just within the mesogloea.

These changes are accompanied (1) by an increase in the number of cells forming the intercanalicular septa (Fig. 33); (2) by the growth of a parenchymatous axial tissue out of cells

which have lost their original connection with the mesogloea, massed within the circlet of canals and increased enormously in bulk by the absorption of water. It is the formation of this tissue that is probably chiefly responsible for the accelerated growth of the stem from the time the axis begins to appear. The canals increase in number and diameter as the stem enlarges and exhibit an internal pressure which prevents their collapse. Yet the great factor in the enlargement seems to be the growth of the axial parenchyma by an increase both in the number and size of its cells.

Observing the loss of importance of the canals as they are forced away from the center of the stem, it would seem natural

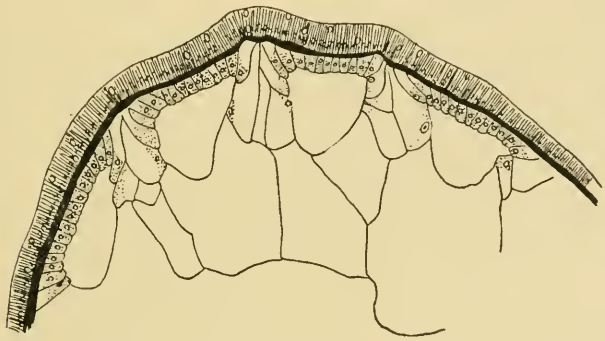


Fig. 33. Portion of transverse section of adult of moderate size, somewhat contracted, showing relation of axial parenchyma to the epithelium of the canals. × 88.

to speak of the axial endoderm as encroaching upon and partially obliterating the original cavity of the stem. Strictly speaking, however, very little if any of the original cavity is obliterated at any time by the axial tissue. On the contrary, the original cavity, divided into several parts, has increased greatly in total cross section, and the axial tissue, instead of encroaching upon it, must be looked upon as a new growth which has affected its form but without which the stem would not have attained its present characteristic size.

There is a certain relation between the number of canals, their diameter and the diameter of the stem. Canals do not appear

until the stem has reached a diameter of about .25 mm. Two to four arise at once, which rapidly subdivide into six to nine. Here they are found at their minimum diameter. From this time they not only increase in number with the diameter of the stem, but the size of each canal and the number of cells in its epithelial boundary also similarly increase.

Space relations appear to determine to some extent the numerical development of the peripheral canals, by fixing the lines along which the vacuolation and intrusion of the future axial cells occur. The essential factor in the formation of the axial parenchyma itself is the growth by absorption of water of epithelial cells. In the first stages of this process, as we have seen, the swollen cells meet across the cavity while retaining their connection with the mesogloea. The subsequent extension of the axis is due to continued growth of the cells composing it and the addition of more cells from the epithelium in such a way that the first formed vacuolated cells are pressed away from the mesogloea and out of the intercanalicular septa by the growth of their successors. The cells occupying the space within the circle of peripheral canals are of enormous size, with exceedingly thin walls and very slight traces of protoplasmic content. There is no evidence that they increase among themselves. Their number is doubtless renewed and augmented from the intercanalicular septa alone, whose cells are themselves derived from the epithelium of the canals.

The peripheral canals are kept open by intercanalicular pressure. Otherwise, the axial tissue does not appear to be subjected to any restraint except that imposed by the length and diameter of the stem. A positive intracellular pressure, then, is the chief factor in the growth of the axial endoderm, and must be reckoned also among the main causes of the growth of the stem.

This view is born out by various facts. The acceleration of the growth of the stem, first, with the appearance of conspicuous vacuoles in the endoderm of the early larva and second, with the formation of the axial endoderm, has been mentioned above. It might be emphasized further, that in the hydranth, where

the vacuolation of the endoderm is not so conspicuous, growth is not so rapid. The suggestion is obvious that there is a causal connection between growth and the absorption of water. In the preceding paper of this series (:04, p. 408), it was said that the stem may not only shorten without increasing its diameter (indicating a loss of water) but may lengthen while actually increasing its diameter (indicating absorption of water). Recently (:05) it was demonstrated that the axial endoderm could respond locally to local conditions by a change of volume. The stem, then, may grow, temporarily at least, by the absorption of water by the axial tissue. It never obtains a permanent length because it is constantly changing in response to stimuli. Its capacity to reach a given length, however, may be taken as a constant, and depends directly upon the number of axial cells and upon their turgidity.

(*c*) *The Axial Parenchyma as a Skeleton.*—Not only does the axial tissue serve as a means by which the length of the stem may be increased. Its presence is correlated with the rudimentary character of the perisarc which is delicate, non-supporting and restricted to the proximal third or fourth of the stem. It is clearly a skeletal tissue, taking the place of the ordinary external chitinous skeleton of most hydroids.

3. *Division of Hydranth Cavity.*—The cushion of vacuolated cells which, in Fig. 27, divides the hydranth cavity into two portions, arises like the axial parenchyma of the stem. Its local development is correlated with the enlargement of the proximal tentacles, whose great length and large size require a reenforcement of the hydranth wall at their base.[6]

4. *The Gonosome.*—The first indications of the gonosome appear when there are about twelve proximal tentacles and but a single enteric canal. Two or three protuberances, approxi-

[6] May (:03) has published a description and figure of the hydranth of *C. pendula* which I refer to only because they are so readily accessible and yet are surprisingly inaccurate, misconceived and misleading. The figure is evidently an oblique section (cf. Fig. 27 of this paper). The so-called longitudinal canals, marked *b*, are but crevices in the parenchyma. There is no sign in the figure of the real base of the hydranth cavity, the fenestrated membrane or the peripheral canals.

mately equidistant, may arise simultaneously just within the circle of proximal tentacles. They are the beginnings of peduncles which later bear medusae. They increase in number gradually throughout the life of the polyp, by the addition of new buds between those already formed. They never equal the number of proximal tentacles. They are larger than the latter, and include at the start a portion of the hydranth cavity. Endoderm and ectoderm are equally involved in the development, which is initiated as a simple evagination. Medusae may arise on the peduncles at an early age, one of them usually developing by a transformation of the end of the peduncle, the others as lateral buds. The peduncles themselves may branch several times. The detailed development of the medusa will not be followed. The reader is referred for it to Allman ('71).

VIII. — Summary and Conclusion.

The more important facts in the post-embryonic period may now be briefly summarized.

The larva is never ciliated or free swimming. Its emergence from the egg case is governed by two sets of factors. Internal factors determine an area of accelerated differentiation which marks the point at which the envelope is dissolved. External factors such as contact and possibly gravity determine the kind of structure (e. g. hydranth or holdfast) which will ultimately appear in connection with the area of differentiation. That is, they determine the polarity of the adult.

The larva elongates as it emerges. Its free (oral) region enlarges and its aboral region narrows. The latter adheres to the substratum, on which it moves by means of amoeboid cells in the ectoderm; the capacity for locomotion is never lost. The elongation of the body is accompanied by a gradual vacuolation of the cells of the endoderm.

The body is next divided into hydranth and stem regions by an external constriction arising from a shortening of the columnar ectoderm cells in its path, and a corresponding internal ridgelike thickening of the endoderm arising from the elongation of the columnar cells in its path. The ridge is more con-

spicuous, and is caused by a local absorption of water by the vacuolated endoderm. About the stem, just below the external constriction, is a thickening in the ectoderm produced by an elongation of cells. Its lower limit marks the future anterior limit of the perisarc, which about this time retreats from the hydranth.

The tentacles appear after hydranth and stem regions have been defined. The distal tentacles arise usually in advance of the proximal, with indications of a typical quartette arrangement. They pause in their development upon reaching the number of four and are then surpassed in number by the proximal tentacles. These numerical relations are soon again reversed, the distal ultimately numbering twice as many as the proximal series.

Histologically, the development of both kinds of tentacles is similar. Its chief features are (1) an increase in number of cells in both endoderm and ectoderm where each tentacle is to appear, (2) a slight evagination of the endoderm and a corresponding thinning of the ectoderm, (3) an extrusion of a single column of cells (four to ten) from the evagination, pushing the ectoderm and mesogloea before it, (4) the arrangement of the axial cells in several rows decreasing in number from base to tip, the longitudinal axes of the cells lying perpendicular to the plane of movement of the tentacles.

The frustules arise similarly in larva and adult, continuing to appear throughout the life of the polyp. Histologically, their origin is similar to the origin of the tentacles, including the incorporation of endoderm and ectoderm cells. Each frustule attains a much greater length and attenuation than the tentacles, owing to the active locomotion of its clavate amoeboid tip and consequent strain on the filament. The connection with the stem is ultimately lost and the organ, for a time independent, dies upon the formation of the perisarcal investment which serves as an anchor for the stem.

In the adult, the frustules are arranged in longitudinal rows, the number of the latter being determined by the number of peripheral canals.

Metamorphosis is accomplished (1) by a shift of the oral boundary of the perisarc through a transformation of the ectoderm of the column, (2) by the development of a fenestrated membrane through local growth and fusion of epithelial cells, followed by a lateral tension; the ultimate fenestration being assisted probably by the currents in the subjoining canals, (3) by the appearance of the peripheral canals, due to the local growth of the endodermic epithelium on certain longitudinal lines and the expression of cells into the enteric cavity. The canals maintain clear passages by internal pressure. Their number and size bear a relation to the diameter of the stem. (4) By growth of the stem, which is largely due to the immense increase in volume of the axial tissue by the absorption of water.

The axial tissue is renewed by the displacement of epithelial cells from the peripheral canals. It acts as a skeletal axis, in the absence of a supporting perisarc.

The division of the hydranth cavity into pre- and post-tentacular portions is connected with the growth of the proximal tentacles.

The gonosome is produced by an evagination of both layers.

The most conspicuous characteristic of the development of *C palma* appears, from the facts just enumerated, to be its plasticity. Long after the close of the segmentation period, when the embryo possesses both an epithelial ectoderm and a mass of endoderm cells fast taking the form of a lining for the developing coelenteron, it still remains for external conditions to fix the oral and aboral poles of the body. This result having been accomplished, the delimitation of hydranth and stem is marked out, before the appearance of a tentacle or frustule, by the subtlest of transformations. A circular depression in the ectoderm, produced by a decrease in the size of certain cells, and a circular ridge in the endoderm produced by a swelling of certain other cells, without any trace of cell division, are the visible signs of the differentiation. Subsequently, all the characteristic organs —tentacles, frustules, peripheral canals, axial endoderm—are moulded in large measure out of more or less differentiated epithelial tissues without recourse to residual cells.

This plastic process of differentiation is accomplished by such means as growth by the absorption of water, mechanical tensions and osmotic pressure. The absorption of water by the larval endoderm accompanies the elongation of the body, which is especially pronounced after the axial parenchyma begins its development and in the region in which it is located, namely, the stem. It is difficult to avoid the suggestion which is thus plainly offered that there is a causal relation between the two facts.

The alterations in ectoderm and endoderm which establish the boundary between hydranth and stem are optically alterations in cell volumes. Especially is the endodermal thickening which develops into the fenestrated membrane initiated by growth processes. The same may be said of the formation of the axial parenchyma of stem and tentacles, as well as the semi-partition of parenchymatous tissue partially separating the pre- and post-tentacular cavities of the hydranth.

The outgrowth of a plug of endoderm cells in the early development of tentacle and frustule forces the attenuation of the ectoderm enveloping it. Lateral strains in the region of the developing fenestrated membrane mechanically produced either by osmotic pressure of the liquid in the enteron, or the contraction of the body, or both, appear to be responsible largely for its final form.

The amoeboid movements of the clavate end of a frustule afford the means by which a strain is put upon the organ that attenuates its cells, both endodermal and ectodermal, reduces and finally ruptures its connection with the stem.

Not only do amoeboid movements of locomotion accomplish form changes. The movements of the tentacles, toward and away from the mouth are correlated with the arrangement of the cells constituting their skeletal axis with their longest diameters perpendicular to the plane of movement. These activities, together with the reaction to contact, are thus factors not only in the behavior but in the construction of the polyp.

Space relations appear unquestionably to exert some influence on the position and numerical development of the tentacles, and on the size and number of peripheral canals. The arrangement

of the frustules upon the latter in longitudinal series introduces an inhibitory factor in the shape of the relatively unproductive vacuolated cells occurring between the canals.

The shift of the perisarc back along the stem at metamorphosis may be interpreted as involving a transformation of cells *in situ* from the covered to the naked variety. The origin of the gonosome from the evagination of endoderm and ectoderm at the base of the hydranth is only another indication of plasticity.

Zoological Laboratory,
University of California,
Berkeley, March 28, 1906.

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CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

XVII.

DINOFLAGELLATA OF THE SAN DIEGO REGION, III. DESCRIPTIONS OF NEW SPECIES.

BY

CHARLES ATWOOD KOFOID.

The investigations of the plankton of the waters off the coast of Southern California, carried on since 1901, principally at the Marine Laboratory at San Diego, have brought to light an exceedingly rich protozoan fauna, in which the Dinoflagellates are abundant and often predominant. In addition to practically all of the species of this order known from warm temperate seas in other parts of the world, there have come to light a number of new forms which are here described. A fuller account of some of them, especially in the genus *Ceratium*, will appear in a later paper.

The present paper includes 22 new forms distributed as follows in the system:

GYMNODINIDAE.
- *Amphidinium sulcatum.*

PERIDINIDAE.
- CERATIINAE.
  - *Heterocapsa pacifica.*
  - *Ceratium californiense.*
  - *Ceratium gallicum.*

Ceratium inclinatum.
Ceratium macroceros deflexum.
Ceratium mollis.
Ceratium ostenfeldi.
Ceratium reticulatum spirale.
Ceratium schranki.
Ceratium tenuissimum.
Ceratium teres.
Gonyaulax pacifica.
Peridinium crassipes.
Peridinium minutum.
Peridinium multistriatum.
Peridinium rectum.

OXYTOXINAE.

Amphidoma biconica.

DINOPHYSIDAE.

Dinophysis diegensis.
Dinophysis diegensis forma curvata.
Dinophysis ellipsoides.
Amphisolenia spinulosa.

Amphidinium sulcatum, sp. nov.

Pl. 22, figs. 1-3.

Body is compressed oval in form, broadly oval in lateral view, ellipsoidal in ventral view. The length 1.7 and the greatest dorso-ventral diameter 1.4 times the greatest transdiameter. Body widest (dorso-ventrally) about midway between the girdle and antapex.

The epitheca is low, its altitude 0.14 of the total length, highest laterally and dorsally and hollowed out toward the longitudinal furrow which passes dorsally beyond the apex.

The hypotheca is broadly rounded posteriorly and very deeply channeled ventrally by the longitudinal furrow which deepens as it passes posteriorly from the flagellar pore. Its depth at the pore is 0.25 of the dorso-ventral diameter at that level and at the antapex it reaches the main axis. The right lip of this furrow is somewhat higher than the left.

The girdle is anterior in position, and the transverse furrow is very deep, sinking obliquely posteriorly into the plasma. It narrows distally to a slender channel displaced posteriorly the width of the proximal end of the furrow. The flagellar pore lies to the left of the tongue of the epitheca extended posteriorly be-

tween the longitudinal furrow and the distal end of the transverse one (Pl. 22, fig. 2). The longitudinal furrow extends from the dorsal half of the epitheca to the antapex, and is a narrow deep channel on the epitheca but widens out on the hypotheca.

The surface is covered by a thin hyaline membrane noted by Stein ('83) but omitted in the generic diagnosis of Schütt ('96). Nucleus spheroidal, in the middle of the hypotheca, with moniliform chromatin reticulum, and two polar centrosomes (?) sunk into its substance. A pyriform vacuole lies near the flagellar pore and small angular yellowish chromatophores are scattered about the amyloid body. Plasma dense and coarsely granular.

Length, 68μ; transdiameter, 35μ; dorso-ventral, 55μ; nucleus, 15μ.

Taken in a vertical haul from 90 fathoms off San Diego in June.

This is the second pelagic species of this genus, the other being *A. aculeatum* Daday ('88) from Naples. The other species of the genus are from fresh (*A. lacustre*) or brackish (*A. operculatum*) water.

Heterocapsa pacifica, sp. nov.

Pl. 22, figs. 4, 5.

A very minute species with prominent asymmetrical spine, resembling *H. triquetra* but less elongated.

Body oval, dorso-ventrally compressed, the length, excluding spine, 1.3 times the transdiameter and 2.1 times the dorso-ventral one. Epitheca exceeds the hypotheca, its altitude 0.75 of the basal transdiameter, its sides slightly convex. Apical pore present. Hypotheca less than 0.5 of the transdiameter in height, slightly asymmetrical, the right side more convex than the left, continued posteriorly in a stout acuminate antapical spine a little to the left of the axis. Its base merges gradually into the outline of the hypotheca and its length is 0.3 of a transdiameter. There is a slight elevation on the right side suggestive of a second rudimentary antapical spine.

The girdle is postmedian; the transverse furrow is impressed, without lists and forms a descending right spiral displaced distally nearly its own width. The longitudinal furrow is faint and

continues posteriorly for half the length of the hypotheca. Thecal wall hyaline, structureless, without suture lines in individuals examined.

Nucleus relatively large, ellipsoidal with moniliform chromatin reticulum. A large spherical amyloid body is present and there are numerous ellipsoidal peripherally located chromatophores of yellowish color.

Differs from *H. triquetra* in its relatively greater transdiameter and consequently stouter form, and in the prominent antapical spine.

Length, including spine, 45μ; transdiameter, 30μ.

In surface oceanic plankton off San Diego in June.

Ceratium californiense, sp. nov.

Pl. 23, figs. 6-9.

Ceratium furca var. *baltica* (in part), Entz (:05), pp. 99-101, Taf. 1, Fig. 8.

Ceratium tripos macroceros (in part), Entz (:05), pp. 101-102, Taf 2, Figs. 13, 14.

This is a small species of delicate habit with slender antapicals curved regularly toward or even beyond the horizontal plane. Midbody resembles that of the *macroceros* group. Tips of the antapicals are closed, acute. The postmargin is wide and abruptly delimited from the bases of the antapicals. Thecal wall hyaline, porulate, but otherwise structureless.

Not in the form cycle of *C. furca balticum* (= *C. lineatum*) and *C. tripos macroceros* (= *C. macroceros*) as suggested by Entz (:05).

Rare in oceanic plankton at San Diego.

Ceratium gallicum, sp. nov.

Pl. 24, figs. 10-12.

Ceratium tripos var. *macroceros,* Gourret ('83), pp. 26-27, pl. 2, fig. 41.

Ceratium tripos var. *macroceras* (in part), Schröder (:00), p. 15, Taf. 1, Fig. 17 f.

Ceratium tripos macroceros (in part), Entz (:05), p. 100, Taf. 2, Figs. 15, 16.

Ceratium tripos macroceros (in part), Karsten (:06), Taf. 23, Fig. 29 c.

A delicate species of the *macroceros* section with deep postindentation and left antapical passing posteriorly from the midbody for a short distance before curving in the major flexure. Both antapicals are convex outwardly.

The midbody is smaller and more rotund than in *C. macroceros* narrowing abruptly into the erect submedian apical horn. The girdle is relatively high, passing some distance above the base of the right antapical. The postindentation is very deep, usually exceeding 0.5 of a transdiameter, and the postobliquity (24°) is less steep than in *C. macroceros* and is set off abruptly from the bases of the antapical horns. The major flexures are more abrupt and the distance between the shoulders is less, in absolute distance, than in *C. macroceros.* The antapicals spread distally in a relatively wide antapical angle which is greater in short-horned (54°–103°) than in long-horned (51°–78°) individuals. Both horns are convex outwardly but the right is usually less curved than the left and often shorter.

The thecal wall is delicate and hyaline and the girdle is often incomplete distally.

Length, 250–480μ; transdiameter, 50–60μ; distance between arms at girdle, 215–295μ; at tips, 300–480μ.

Common in oceanic plankton at San Diego. Eupelagic in warm temperate and tropical seas.

Ceratium inclinatum, sp. nov.

Pl. 25, figs. 16-21.

"*Ceratium tripos patentissimum* Ost.", Karsten (:06), p. 144, Taf. 21, Figs. 23, 23*a*. Symmetry reversed in his figures.

A small species of delicate habit, with narrow shoulders, slight postindentation, and spreading antapicals distally incurved, with contracted but still open tips, sometimes slightly inflated distally. The antapical angle is usually 60°–80°. Differs from *C. ostenfeldi* in its more delicate habit, smaller size, lesser antapical angle, and in the tips of the antapicals; from *C. macroceros* in the tips, narrower shoulders and more delicate habit.

Length, 240–510μ; transdiameter, 32–42μ; distance between horns at girdle, 95–150μ; at tips, 225–440μ.

Abundant at times in the oceanic plankton off San Diego.

Ceratium macroceros deflexum, subsp. nov.

Pl. 24, figs. 13-15.

This is a warm water subspecies of *C. macroceros* with moderate postindentation, but differing from the type in the marked ventral deflection of the antapicals in their proximal regions. As a result of this position, the antapicals, seen from either face, approach a course subparallel to the apical horn and the distance between them is considerably narrowed as compared with the distance in *C. macroceros.* In extreme cases the dorso-ventral distance of this ventral deflection exceeds one transdiameter. The postindentation of this subspecies is nearly equal to that in the typical *C. macroceros.*

Length, 300–420μ; transdiameter, 52–62μ; antapical angle, 0°–16°.

Occasionally taken in plankton of tropical character at San Diego.

Ceratium mollis, sp. nov.

Pl. 27, fig. 26.

Ceratium tripos flagellifera forma *angusta* (in part), Karsten (:06), Taf. 22, Fig. 33*b*.

A small species of delicate habit with all three horns greatly elongated and subparallel, rounded tips and slight postindentation. The midbody is small, rotund, with erect apical horn 6–12 transdiameters in length. The hypotheca is low, with slight postindentation, not abruptly delimited from the bases of the antapicals, often with small fin. The postobliquity is rather steep, 30°–50°. The major flexures of the antapicals are completed within 2 transdiameters of their bases. Their course beyond the flexure is approximately parallel to that of the apical at a distance from it of 1.5–2 rarely 2.5 transdiameters. They are delicate and somewhat flexible, exhibiting considerable range of curvature, sinuosities and undulations. Their tips are broadly rounded with terminal pore open or obscure. Thecal wall is hyaline and structureless.

The species differs from Schröder's ('00) *C. tripos* var. *macroceros* forma *longissima,* which is probably a valid species, *C.*

longissimum (Schröder), and from the form figured by Schütt ('93, fig. 21, Va) in its postindentation, median position of the apical on the epitheca, in its much smaller size, more sinuous horns and delicate habit. Karsten's (:06) *C. tripos flagellifera* forma *angusta* includes (his figure 33*a*) *C. inflexum* Gourret and this species (his fig. 33*b*) which differs from *C. inflexum* in its narrower shoulders, less localized major flexures, and greater postobliquity.

Length, 260–430μ; transdiameter, 35–40μ.

Rare in plankton of tropical character at San Diego.

Ceratium ostenfeldi, sp. nov.

Pl. 26, figs. 22-25.

Ceratium volans, Ostenfeld og Schmidt(:01), p. 168, fig. 21. This is not *C.* (*tripos* var.?) *volans* Cleve (:00), p. 15, pl. 7, fig. 4. Cleve's species is *C. carriense* Gourret.

Ceratium (*tripos* var.) *vultur*, Okamura and Nishikawa (:04), pp. 123-124, pl. 6, fig. 8. Also as *C.* (*tripos* var.) *vulture*.

Ceratium volans Cleve forma, Schröder (:06), p. 363, fig. 34.

A very large species of the *macroceros* group, of robust habit, long, spreading, straightish, symmetrical antapicals with open tips. Deep postindentation. Antapical angle 85°–90°. Antapicals not so spreading as in *C. carriense*, and more so than in *C. macroceros*.

Length, 530–740μ; apical horn, 390–665μ; antapicals, 435–675μ; distance between arms at girdle, 300–380μ; at tips, 675–920μ.

Eupelagic in warm temperate seas.

In material examined by me this species is distinct from both *C. carriense* Gourret and *C. macroceros* (Ehrbg).

Ceratium reticulatum spirale, subsp. nov.

Pl. 27, figs. 27, 28.

Differs from *C. reticulatum* Pouchet ('83) [= *C. hexacanthum* Gourret and *C. tripos* var. *inaequale* Gourret ('83); not *C. reticulatum* Imhof ('83)] in the fact that the left antapical is not only carried across the apical on its ventral (occasionally dorsal) side but is coiled up in a nearly flat spiral of 1–4 turns.

The center of the spiral lies just anterior to the base of the apical horn and its plane is oblique from the left dorsally to the right ventrally at an angle of about 30°–45° to the frontal plane. The diameter of the coil is 1–2 transdiameters. The spiral is quite regular, the interval between the turns being 2–3 times the diameter of the horn and increasing slightly from the center to the periphery of the coil. The surface reticulations of the midbody, postmarginal fin, form of the right horn and dimensions are similar to those of *C. reticulatum* in its longer horned forms.

In oceanic plankton of tropical character off San Diego.

Ceratium schranki, sp. nov.

Pl. 28, figs. 29*a*-31.

Ceratium (*tripos* var.) *arcuatum* (in part), Okamura and Nishikawa (:04), p. 122, pl. 6, figs. 3, 3*a*.

Ceratium tripos arcuatum (in part), Entz (:05), pp. 107, 109, Taf. 5, Figs. 31, 32, Taf. 6, Fig. 45.

Ceratium tripos lunula (in part), Karsten ('06), pp. 142-143, Taf. 20, Figs. 12*a*, 12*b*.

A large robust species related to *C. arcuatum*, having regularly curved, balanced, often subequal antapicals, and almost semicircular posterior outline.

The midbody is less rotund than in many species of the *tripos* group and the margins of the epitheca are but slightly convex or even concave. The apical horn is not so much displaced as in *C. arcuatum* and is stout and heavy and often relatively short. The distal part of the girdle is crowded close to the base of the right horn. The postmargin of the midbody is not set off from the bases of the antapicals by any indentation and its curvature is continued without marked change in its radius till the antapicals attain a direction parallel to the apical where the curvature slackens and the horns continue distally with little, if any, curvature toward the axis. The posterior border is thus a semicircle whose radius equals approximately two transdiameters. The distance between the antapicals at the level of the base of the apical is 3–3.5 transdiameters. The antapicals are stout and heavy with closed pointed tips and are often approximately equal in length. Occasionally the right horn exceeds the left in length. Often found in chain formation.

This species differs from *C. arcuatum* in its subequal antapicals, wider arc, and more contracted epitheca.

Length, 350–425μ; transdiameter, 65–95μ; distance between horns at level of base of apical, 290 to 370μ; between tips, 310 to 400μ.

Common in plankton of tropical character off San Diego.

Ceratium tenuissimum, sp. nov.

Pl. 29, figs. 32, 33.

A minute species resembling *C. carriense* but much smaller with delicate attenuate spreading antapicals.

The midbody is very small, rotund, with erect apical, 3–8 transdiameters in length. The postmargin is scarcely differentiated from bases of the antapicals and the postobliquity (15°) is not very steep. The antapicals spread laterally with slight major flexures, the right forming an angle of 50°–80° and the left of about 90° with the apical. The antapicals are straight or in many cases slightly reflexed *posteriorly* but less pronouncedly than in a form of *C. carriense* which Schröder (:06) has described as *C. hundhausenii*. All intergradations between straight and curved horns are found. I do not regard such curvature as of specific significance. It is more common in *C. tenuissimum* than in *C. carriense* as I have observed it. The antapicals are attenuate distally and the tips are open or sometimes contracted. Thecal wall hyaline, girdle often obsolete distally. The three horns are usually subequal in length.

This species is a fifth, or less, of the size of the typical forms of *C. carriense* (= *C. patentissimum* Ost. et Schm.), which it resembles in its proportions. I find no intergrading connections and regard this smaller form as a distinct species.

Length, 100–430μ; transdiameter, 35–45μ; distance between tips of antapicals, 215–850μ.

In oceanic plankton off San Diego.

I retain Karsten's (:06) name "*recurvata*" for the relatively rare forms with the tips of the antapicals recurved posteriorly. In the typical species the antapicals are not thus recurved. These recurved forms do not belong, as Karsten indicates, to "*Ceratium tripos volans*" but to the species here described.

Ceratium teres, sp. nov.

Pl. 29, figs. 34-36.

A minute species related to *C. eugrammum* (Ehrbg. '59 and '73) but of more delicate habit. It differs from *C. eugrammum* in its fusiform midbody. The lateral margins of the epitheca are convex and the hypotheca is contracted distally. The antapicals are short, the right diverging 25° to 30°. The postmargin is relatively wide and the postobliquity is not so steep as in *C. eugrammum.* The thecal wall is hyaline and structureless, and is very delicate on the horns, and comparatively thick on the midbody. Pores very faintly marked, suture lines rarely evident.

Length, 160–210μ; transdiameter, 33–37μ.

Rare in oceanic plankton off San Diego.

Gonyaulax pacifica, sp. nov.

Pl. 30, figs. 37-39.

An elongated species with a single asymmetrical antapical horn and suture lines marked by parallel longitudinal striae.

Body broadly fusiform, rounded posteriorly and somewhat flattened on the ventral face. Total length nearly twice transverse diameter at girdle. Compressed laterally, ratio of transverse and dorso-ventral diameters, 1 to 1.2. Epitheca a cone whose lateral faces are slightly concave and whose altitude is about equal to the diameter of the spreading base. Hypotheca dome-shaped, abruptly rounded posteriorly and flattened and excavated on ventral face, flaring at the girdle. Its altitude about three-fifths of its transdiameter at girdle. The hypotheca is prolonged at the left of the median line in a stout acute antapical spine about one-seventh of the diameter at the girdle in length.

Girdle located about five-ninths of the total length from the apex, its plane perpendicular to the axis. Transverse furrow narrow, its width a little more than one-twentieth of the transdiameter, forming a descending right spiral with displacement nearly twice its width and most of its curvature near the distal end, deeply impressed, with sharply angled overhanging margins formed by the flaring bases of the epitheca and hypotheca. Flagellar foramina located at the displaced ends of the transverse furrow. The longitudinal furrow was obscured in the specimen.

but it appears to extend from a collared apical pore to a broadly expanded posterior end near the antapex, and to be somewhat narrower on the epitheca than on the hypotheca.

Thecal plates as follows: 6 apical, of which 5 are wedge-shaped and one, the furrow plate, almost linear; 6 precingular; 6 postcingular, and 1 longitudinal ventral furrow plate; 1 antapical with postero-dorsal exposure; and the ribbon-like girdle plate. Surface marked by a few scattered longitudinal striae and scattered pores. Transverse furrow ribbed at regular intervals. Suture lines often marked by 2–5 approximated parallel striae between some of which cross striae appear in places.

Only the skeleton thus far observed.

Length, 142μ; transverse diameter at girdle, 92μ; altitude of epitheca, 92μ; of hypotheca, 78μ; width of girdle, 5.5.

Singly in oceanic plankton off San Diego in summer.

Peridinium crassipes, sp. nov.

Pl. 31, figs. 46, 47.

A medium-sized species related to *P. depressum*, with oblique girdle and short, stout antapicals.

The body is low and stout, its length being 1.1 transdiameters. It is slightly dorso-ventrally flattened, the greatest dorso-ventral diameter being 0.9 of the transdiameter. It is excavated ventrally and has a reniform girdle section.

The main axis is deflected antero-dorsally from a perpendicular to the plane of the girdle at an angle of 15°. The ventral face of both epitheca and hypotheca is somewhat concave, but the dorsal convex. There is no apical horn and the antapicals are short and stout, the greatest depression of the postmargin being about 0.15–0.2 of the transdiameter. This species is characterized primarily by the form of the end of the antapicals. Instead of terminating distally in a single conical projection, each ends in a blunt semitruncated projection with two or three principal points, one of which is homologous with the tip of the antapical and the other two represent respectively dorsal and ventral angles of the wide (dorso-ventrally) postmargin which forms in a dorso-posterior view a sort of an arch with wider posterior and narrow anterior opening. The median ventral points are formed by posterior extensions of the lists of the longitudinal furrow.

The transverse furrow is impressed, with ribbed membranous lists. It has strong proximal arch and little distal displacement.

Thecal wall with three mid-dorsal epithecal plates, sutures with broad bands of intercalary striae, surface areolated, with nodal pores. Plasma reddish.

Length, 80–90μ; transdiameter, 67–80μ.

Common in neritic plankton in summer off San Diego.

Peridinium minutum, sp. nov.

Pl. 31, figs. 42-45.

A minute species of globular form with a low apical horn and no antapical extension. Two dorsal intercalary plates instead of three.

The body is spherical, without ventral flattening or excavation. The epitheca slightly exceeds the hypotheca and ends in an abruptly differentiated stout apical horn whose diameter is 0.7 and height 0.5 of the width of the transverse furrow. The hypotheca plus the girdle is about equal to the epitheca. It has no antapical horns or spines. The girdle is horizontal and not displaced. The lists of the transverse furrow are low hyaline fins. The longitudinal furrow expands posteriorly and is bordered by membranous lists with two distal ribs and one in the highest part of the left list. Thecal wall hyaline, porulate, without reticulations (in individuals thus far examined). Sutures marked by well defined lines and short intercalary striae.

Differs from *P. globulus* in the presence of the short apical, the non-displaced girdle and its smaller size.

Length, 23–43μ; transdiameter, 23–47μ.

Abundant in May in San Pedro Harbor, California.

Peridinium multistriatum, sp. nov.

Pl. 30, figs. 40, 41.

A medium-sized species without apical or antapical horns, characterized by thick walls with exceedingly wide striated intercalary bands.

The body is rotund, subpentagonal in face view. Its length and transdiameter are about equal but exceed the dorso-ventral diameter. The epitheca is slightly contracted to a low eminence containing the slit-like apical pore and flares as it approaches the

salient girdle. It is but little larger than the hypotheca, which has no antapical horns but only small acute points near the ventral side of the antapical plates. There are no spines or fins as in *P. steini* Jörg. The girdle is narrow and deeply impressed and the transverse furrow forms an ascending right spiral with a distal displacement equal to its width. The longitudinal furrow is short and shallow, reaching only half way to the postmargin.

There are three dorsal intercalary plates. The suture lines are marked by exceedingly wide bands of intercalary striae. The reticulated surface of the plates is correspondingly reduced. A median row of thickenings on the striae marks the suture lines. The plates are punctate with numerous minute pores. Plasma dense, chromatophores brownish.

Length, 88μ; transdiameter, 88μ.

Rare in oceanic plankton off San Diego in June and July.

Peridinium rectum, sp. nov.

Pl. 32, figs. 48, 49.

A small species related to *P. pedunculatum* Schütt, but having a sharply differentiated, straight antapical horn of uniform calibre.

The body is ellipsoidal or less ovoidal than in *P. pedunculatum* and passes abruptly into a short straight apical horn, 0.1–0.2 of the transdiameter in length. The horn often flares a little at the aperture but is not swollen as in *P. pedunculatum.* The girdle is slightly postmedian, the transverse furrow is not impressed, has thin hyaline lists and its distal end is displaced anteriorly from 0.3 to 0.9 of its width. The two antapical spines are finned, subequal, 0.3–0.5 of a transdiameter in length. Thecal wall hyaline, structureless. Plasma rosy.

Length, excluding horn and spines, 52μ; transdiameter, 43μ.

Common in midsummer in oceanic plankton off San Diego.

Amphidoma biconica, sp. nov.

Pl. 32, figs. 50-52.

A medium sized biconical species with wide girdle.

Body biconical, ends acuminate, epitheca and hypotheca approximately equal, ratio of their lengths 10:11. Epitheca a low cone with its sides straight or slightly concave, equaling in length

the diameter of the base and somewhat recessed and concave on ventral face. Hypotheca of similar proportions but slightly larger, with straight or slightly convex sides, also concave on the right ventral face. Transverse furrow wide, about one-tenth of the length in width, forming a descending right spiral with a displacement of 1.2 times its width, deeply excavated, with low heavy lists. Longitudinal furrow small, short and shallow, to the left of the concave ventral face. Plates of the generic pattern, antapicals very short, apicals long, sutures marked by rugose ridges along the middle of the faint intercalary striae. Shell with secondary longitudinal striae and intervening reticulations forming irregular polygons. Transverse furrow traversed by the longitudinal sutures and striae.

Plasma dense, translucent (in fixed material), nucleus mid-ventral, reniform, chromatophores large, ellipsoidal, yellowish with brown center. About 15–20 disc-shaped and ellipsoidal perforate skeletal (?) inclusions in plasma mainly in the epitheca, the single ones resembling the elements in the epithecal skeleton of *Amphilothus elegans* as figured by Schütt ('95, Taf. 27, Fig. 102) but without their arrangement in a definite pattern. I have seen similar inclusions but larger and less regular in the endoplasm of a large holotrichous ciliate of the plankton in which this species is found but am unable to determine from the scanty data at hand, whether they are indigenous or adventitious with food in the ciliate. Indeed this latter possibility is not entirely excluded in the case of *Amphidoma*, for as Schilling ('91) has shown, there is a possibility that holozoic nutrition may occur in some *Dinoflagellata*. These structures do not resemble any known *Coccolithophoridae* and I know of no organisms in the plankton having normally such skeletal structures.

This species differs from *A. nucula* Stein, the only other well established species in the genus in its reversed proportions of epitheca and hypotheca, wider girdle, longer apical and shorter antapical plates, in its rugose suture lines, surface structure and skeletal (?) inclusions.

Dimensions: length, 71μ; diameter at girdle lists, 41μ.

Taken in vertical haul from 70 fathoms, 7 miles off Pt. Loma in July.

Dinophysis diegensis, sp. nov.

Pl. 33, figs. 57-61.

D. homunculus (in part), Stein ('83), Taf. 21, Fig. 8. "Ein junges Individuum."

A small species with elongated, laterally compressed body, pointed antapex, but lacking the dorsal elevation found on *D. homunculus.*

The body is stouter than in *D. homunculus,* its length, excluding lists, being 2.5 times its dorso-ventral diameter. It is much compressed laterally, its transdiameter being less than 0.5 of the dorso-ventral diameter.

The epitheca is exceedingly low, being less than 0.5 of the width of the transverse furrow in height and almost without convexity. The hypotheca has its dorsal and ventral margins almost parallel as far as the level of the posterior rib of the ventral fin. There is a little convexity in the dorsal outline and a slight local swelling in some individuals at the flagellar pore on the ventral margin. From approximately at the level of the posterior rib the posterior third of the hypotheca is contracted to a bluntly rounded point. Both margins are concave, the dorsal more so than the ventral. The antapex is rarely curved ventrally as in forma *curvata* (Pl. 33, fig. 58).

The collar lists are lower and less oblique than in Stein's ('83) figure, being relatively heavy low ridges. The height of the anterior one about equals the width of the furrow and is higher ventrally than dorsally. The posterior one is about half this height and more flaring. The plane of the girdle is oblique to the main axis postero-ventrally at an angle of 25°. The anterior collar is closed ventrally across the suture between the valves by a thin lamella.

The longitudinal fin arises from the rib on the proximal angle of the posterior collar and continues posteriorly for about 0.6–0.7 of the length of the body. The suture spine lies posterior to the middle of the fin and a more or less prominent posterior spine arises beyond the end of the longitudinal furrow. The fin in some individuals continues beyond this spine and is shortly confluent with the ventral margin. The fin crosses from the left to the

right valve at the suture spine. The pore and longitudinal furrow lie upon the right valve. Flagellar pore more posteriorly located than usual in *Dinophysis*, being near the base of the suture spine.

The thecal wall is delicate and hyaline with numerous fine pores, 12–20 across the valve. The suture is marked by a prominent line.

The plasma is hyaline, and contains a posteriorly located nucleus, and scattered irregular yellowish chromatophores.

In the many individuals of this species which I have seen, no evidence appears that this is a "young" individual of *D. homunculus*, as Stein ('83) states. It appears to be a perfectly distinct species of small size, different form and habitus. It varies in the outline of the antapical region, the protuberance of the flagellar pore and the distinctness of the pores on the valves.

Length, 55–110μ; dorso-ventral diameter, excluding fin, 23–44μ.

Rare in neritic plankton in the summer off Southern California. Taken off San Diego and La Jolla, and in San Pedro Harbor.

Dinophysis ellipsoides, sp. nov.

Pl. 33, fig. 56.

A small hyaline species with ellipsoidal, laterally compressed body and low collars.

Body symmetrically ellipsoidal, its length 1.6–1.7 times the greatest dorso-ventral diameter. Transdiameter about 0.3–0.4 of the dorso-ventral diameter. Epitheca very low, scarcely convex. Hypotheca broadly and symmetrically rounded at the antapex, equally convex dorsally and ventrally except in the region anterior to the flagellar pore which is slightly concave. Girdle nearly perpendicular to the main axis. Collar lists low and flaring, the posterior lower than the anterior, and diminishing in elevation toward the distal end. Anterior collar faintly ribbed. Longitudinal fin with three ribs, one at the anterior angle, a middle suture spine and a recurved posterior one. The fin is abruptly decurrent behind the posterior spine.

Thecal wall very thick but exceedingly hyaline. Sagittal suture scarcely marked, pores minute, about 20 across the valve. A

large, laterally compressed, posteriorly located nucleus and a few irregular pale chromatophores in the hyaline plasma.

Differs from *D. acuta, D. sacculus* and *D. rotundata* in its symmetrically ellipsoidal body and very hyaline aspect.

Length, excluding collar, 43μ; dorso-ventral diameter excluding fin, 25μ.

Rare in neritic plankton off San Diego in midsummer.

Amphisolenia spinulosa, sp. nov.

Pl. 32, figs. 53-55.

A large species related to *A. palmata* Stein but without terminal expansion of the antapical horn and with no lateral spinule.

The body is elongated, its total length about 40 times the greatest dorso-ventral diameter of the midbody. Neck and head, midbody and antapical horn forming respectively 0.1, 0.3, and 0.6 of the total length. The head is depressed, with convex upper and under surface, and impressed furrow. It is oblique (30°) to the main axis. The neck is of nearly uniform calibre, and is channeled ventrally as it approaches the flagellar pore. The midbody is elongated, fusiform, tapering gradually into the long apical horn. This is of a nearly uniform calibre and is deflected distally to the right and ventrally in a curve in its terminal third. It is not expanded distally as in *A. palmata* but bears a similar group of three, short, equal, divergent, terminal spinules. There is no lateral spinule as in *A. palmata.* Chromatophores subspherical, or irregular.

Length, 740–800μ; greatest dorso-ventral diameter, 18–20μ; diameter of antapical horn, 3–5μ.

Taken in oceanic plankton off San Diego in June and October.

Zoological Laboratory, University of California,

March 31, 1907.

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EXPLANATION OF PLATES.

PLATE XXII.

Fig. 1. Lateral view of *Amphidinium sulcatum*, sp. nov. × 850.

Fig. 2. Ventral view of same. × 850.

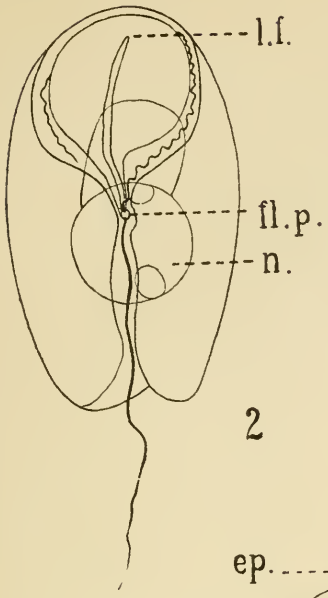
Fig. 3. Dorsal view of same. × 850.

Fig. 4. Ventral view of *Heterocapsa pacifica*, sp. nov. × 1370.

Fig. 5. Dorsal view of same with cell contents. × 1370.

ABBREVIATIONS.

amy.—amyloid body.
chr.—chromatophore.
cp.—epitheca.
fl.p.—flagellar pore.
l.f.—longitudinal furrow.
n.—nucleus.
tr.f.—transverse furrow.
vac.—vacuole.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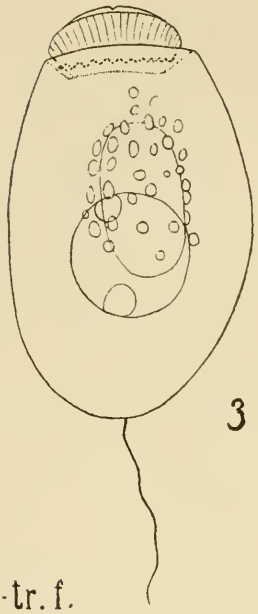
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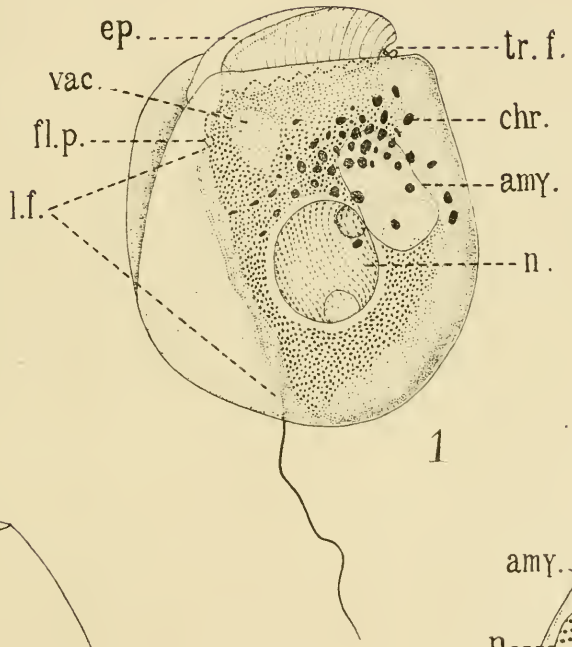
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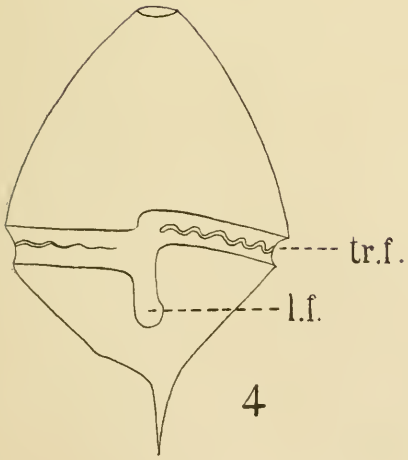
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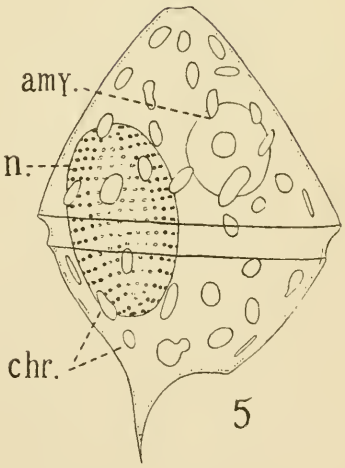
amy.
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chr.
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PLATE XXIII.

Fig. 6. Ventral view of *Ceratium californiense*, sp. nov. × 155.

Fig. 7. The same of another individual. × 155.

Fig. 8. Ventral view of individual with abnormally long horns showing distal zone of recent growth in apical horn and proximal zones in the antapicals at points marked by asterisk. × 450.

Fig. 9. Dorsal view of same. × 450.

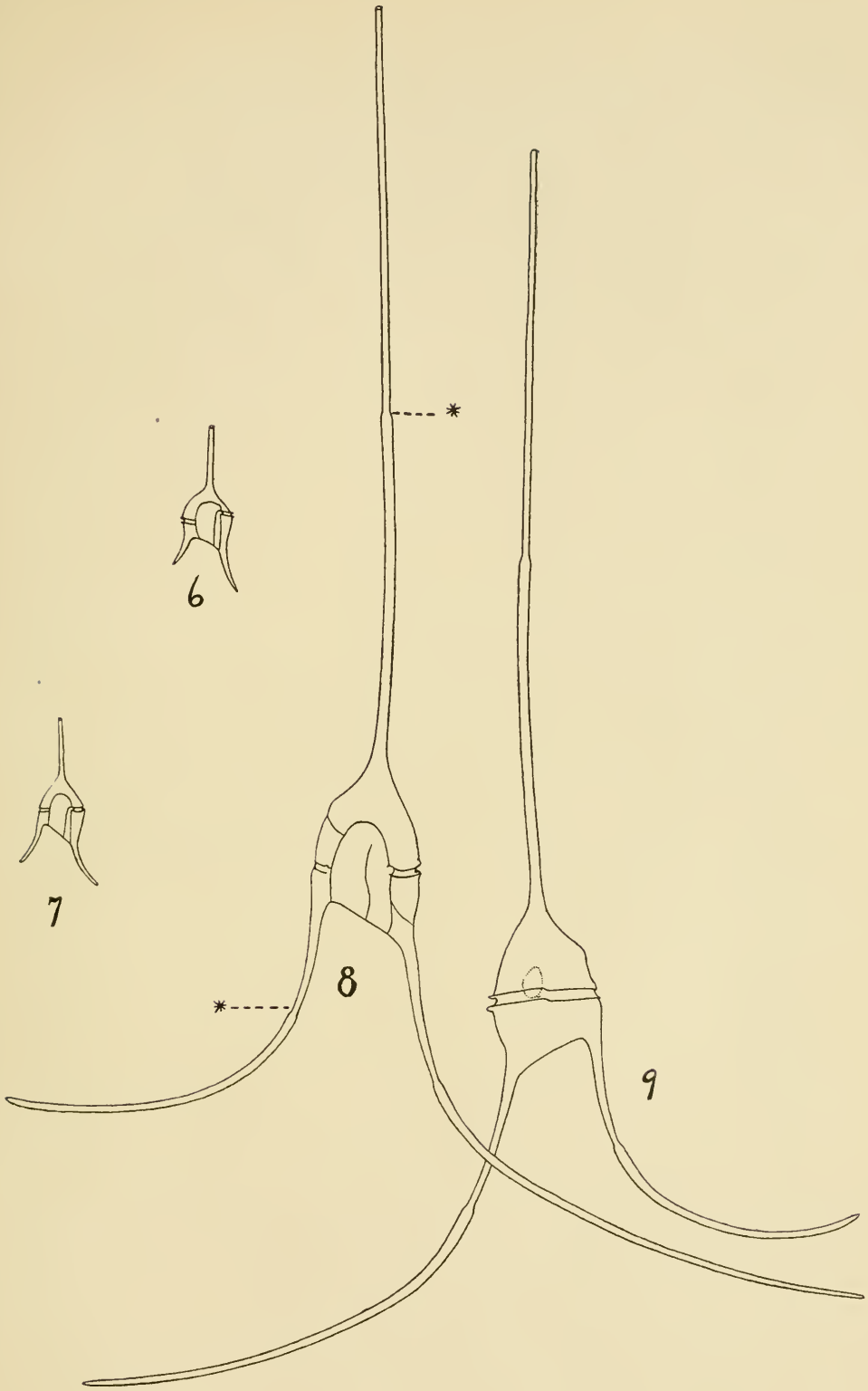
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PLATE XXIV.

Fig. 10. Ventral view of *Ceratium gallicum*, sp. nov. × 313.

Fig. 11. Dorsal view of same. × 313.

Fig. 12. Cell contents of same. × 313.

Fig. 13. Ventral view of *Ceratium macroceros deflexum*, subsp. nov. × 100.

Fig. 14. Lateral view of same. × 100.

Fig. 15. Dorsal view of same. × 100.

ABBREVIATIONS.

chr.—chromatophores.
n.—nucleus.
vac.—vacuole.

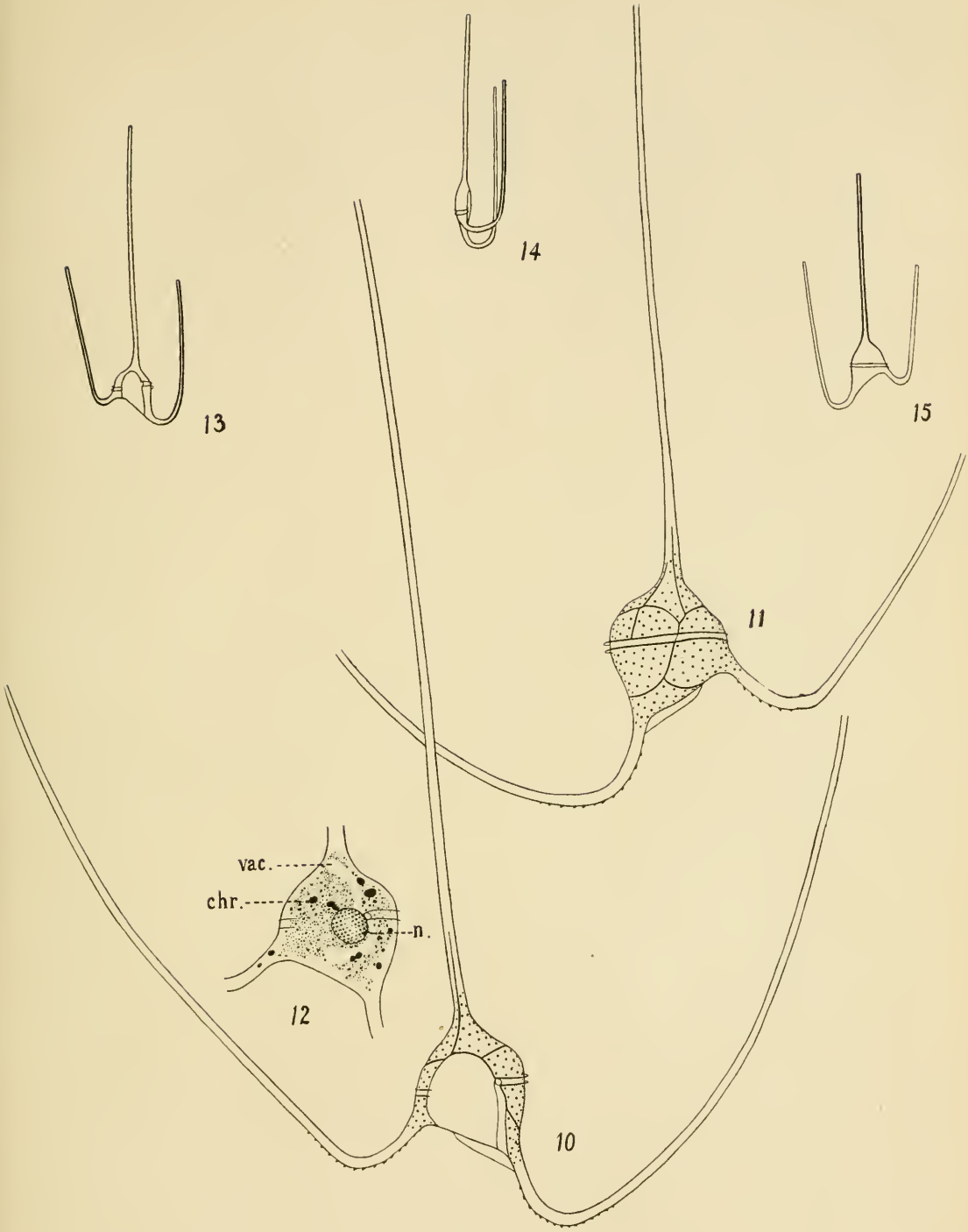
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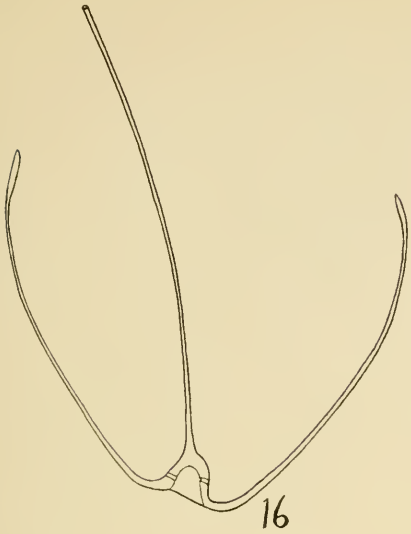
PLATE XXV.

Figs. 16-18, 20. Ventral views of *Ceratium inclinatum*, sp. nov. × 155.
Figs. 19, 21. Dorsal views of same. × 155.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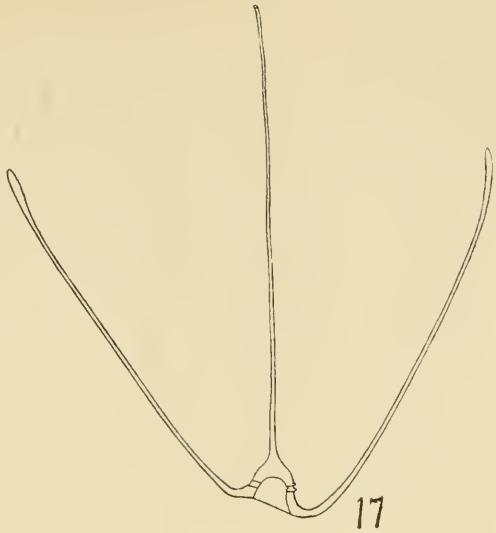
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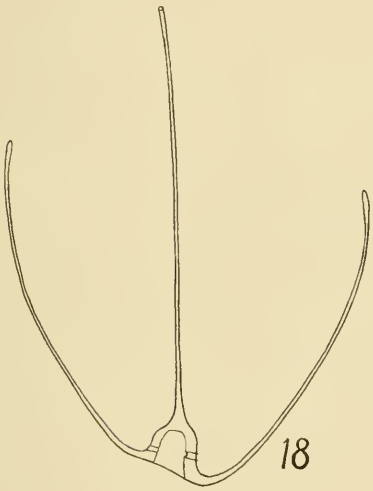
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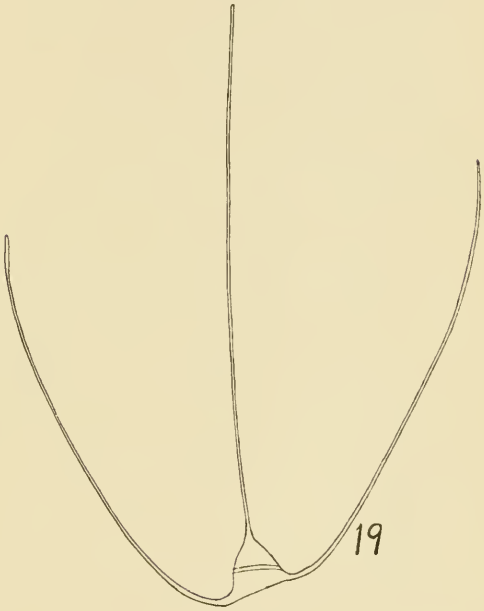
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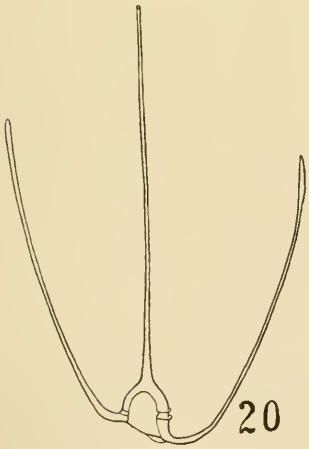
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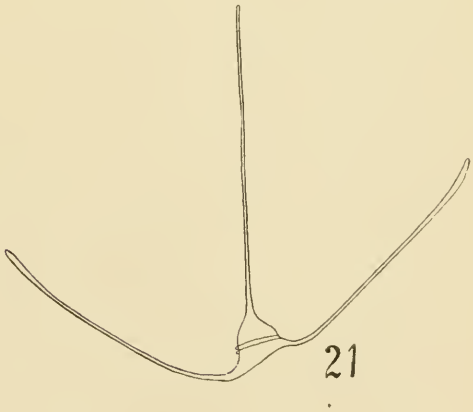
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PLATE XXVI.

Fig. 22. Ventral view of *Ceratium ostenfeldi*, sp. nov. × 313.

Fig. 23. Dorsal view of same. × 313.

Fig. 24. Ventral view of individual with wide antapical angle. × 100.

Fig. 25. Dorsal view of a second individual. × 100.

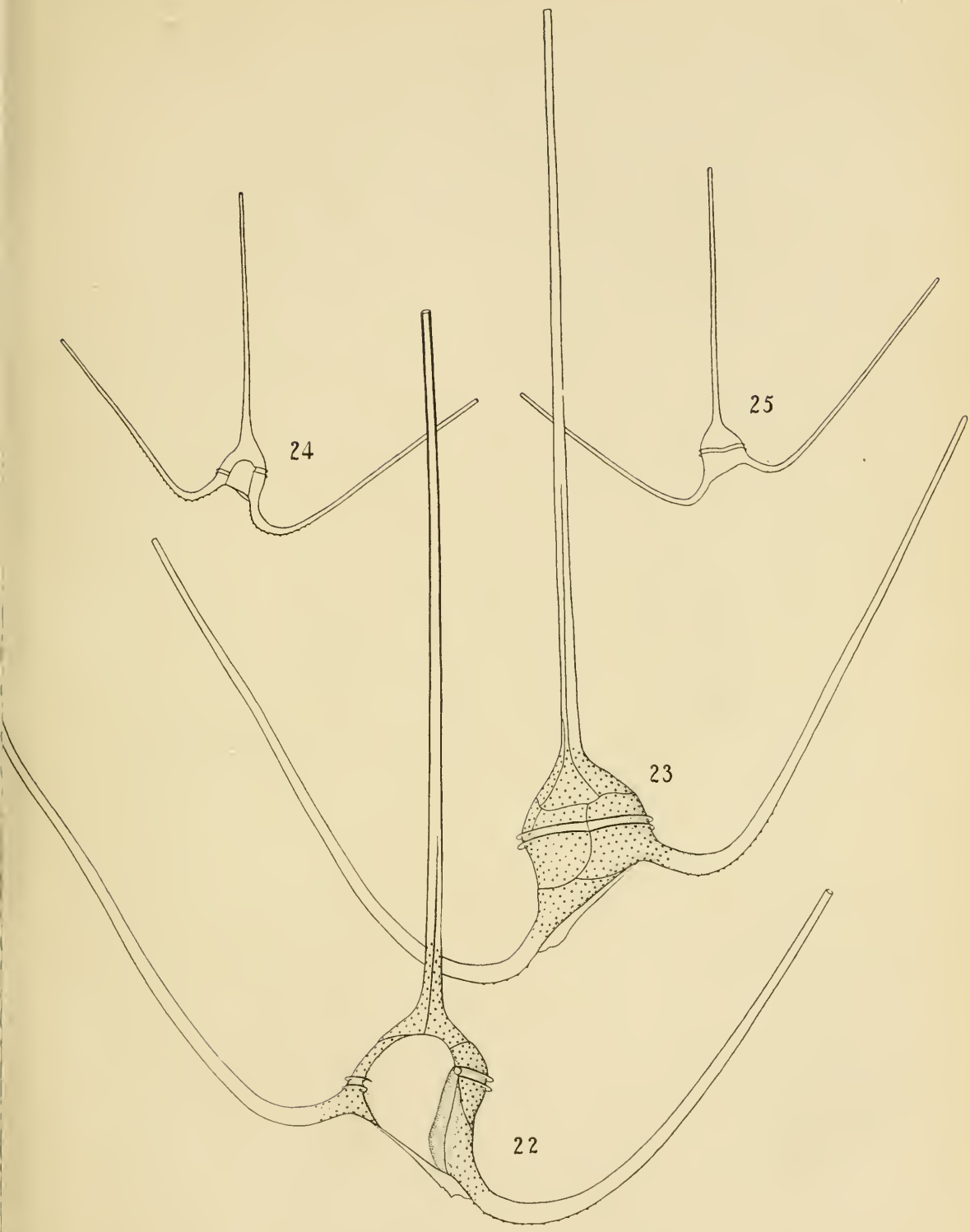
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PLATE XXVII.

Fig. 27. Dorsal view of *Ceratium reticulatum spirale*, subsp. nov. × 313.

Fig. 28. Dorsal view of another individual with a more completely coiled antapical. × 135.

Fig. 29. Dorsal view of *Ceratium mollis*, sp. nov. × 280.

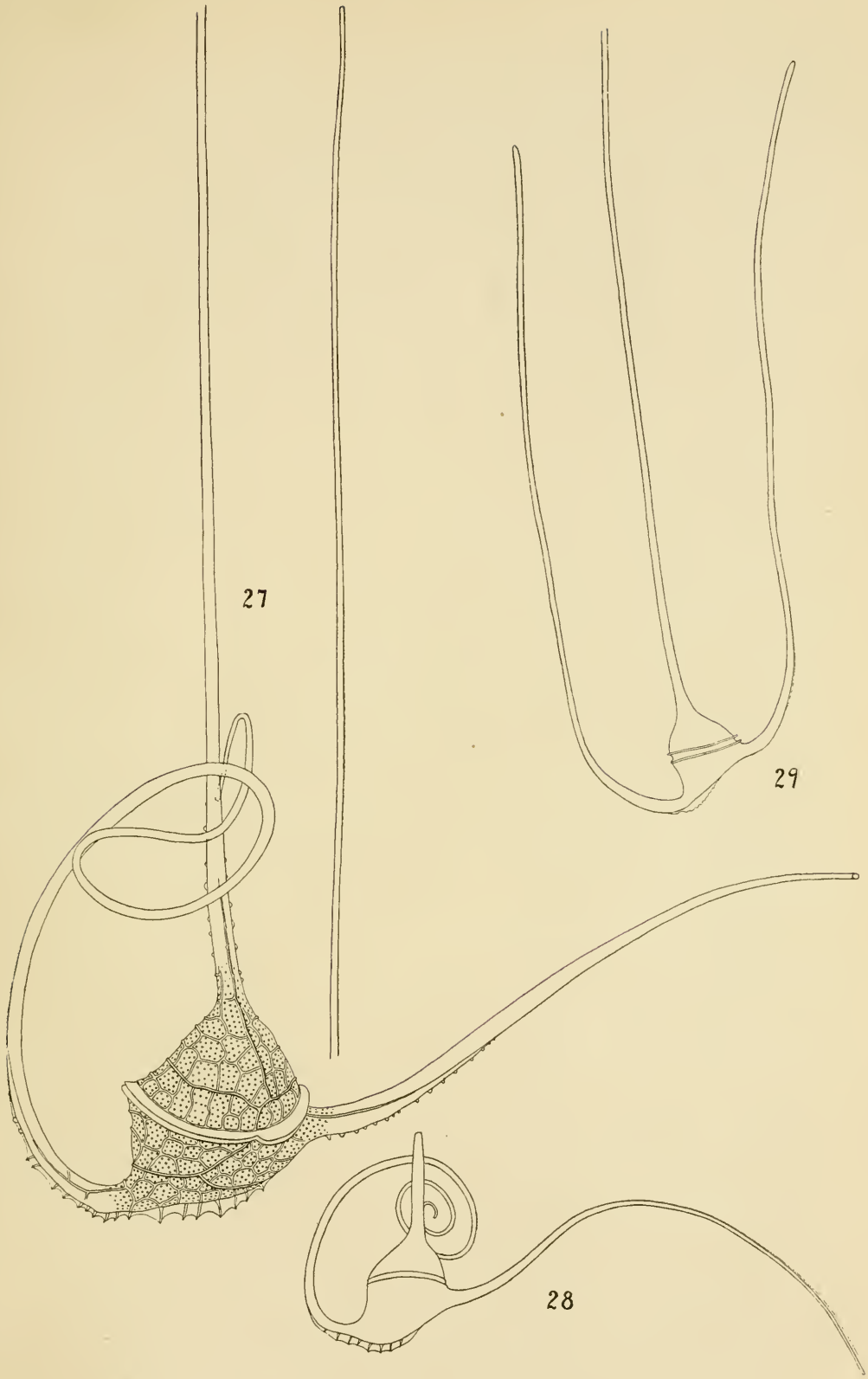
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PLATE XXVIII.

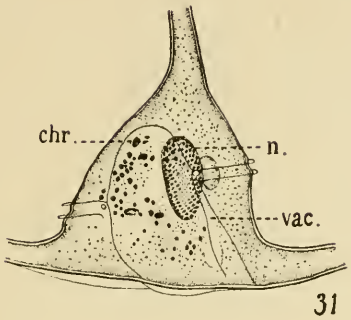
Fig. 29*a*. Ventral view of *Ceratium schranki*, sp. nov. × 387.

Fig. 30. Dorsal view of same. × 387.

Fig. 31. Cell contents of same. × 387.

ABBREVIATIONS.

chr.—chromatophores.
n.—nucleus.
vac.—vacuole.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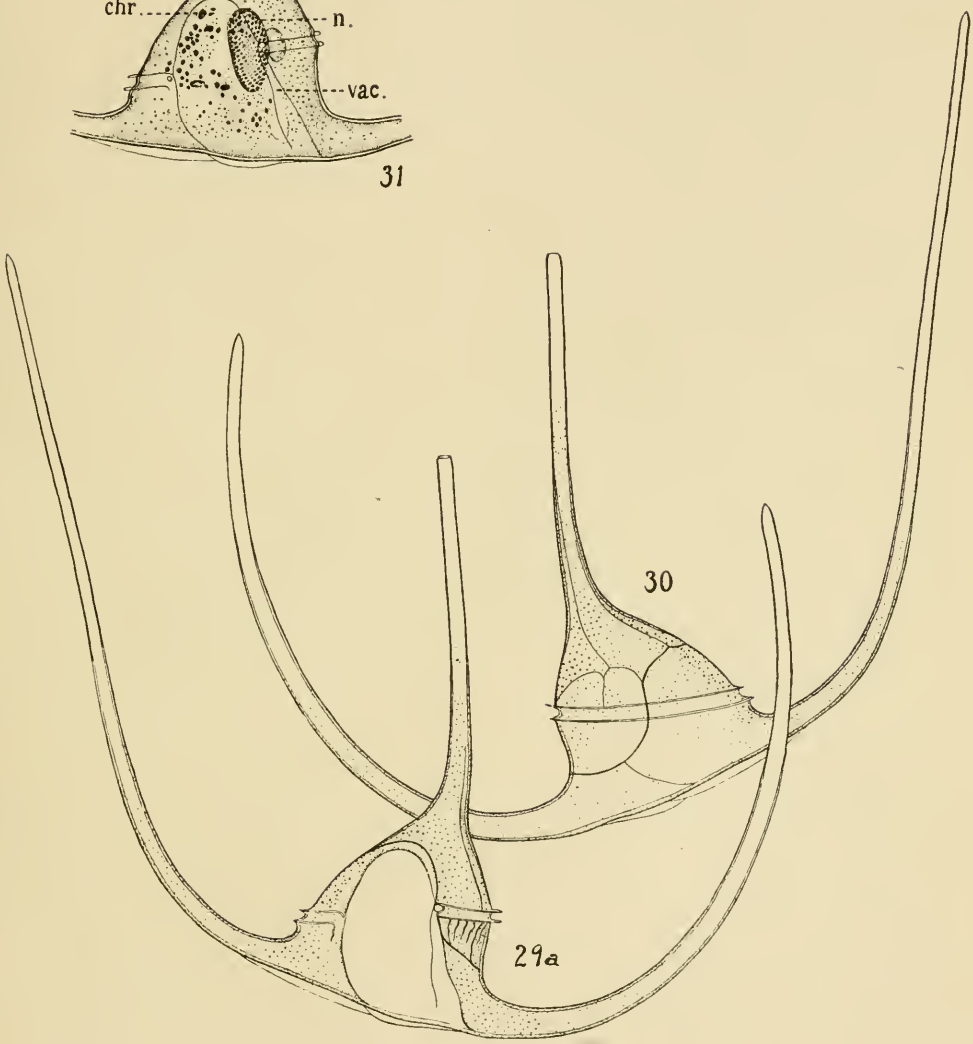
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PLATE XXIX.

Fig. 32. Ventral view of *Ceratium tenuissimum*, sp. nov. × 286.

Fig. 33. Dorsal view of same. × 286.

Fig. 34. Ventral view of *Ceratium teres*, sp. nov. × 400.

Fig. 35. Dorsal view of same. × 400.

Fig. 36. Cell contents of same. × 400.

ABBREVIATIONS.

chr.—chromatophores.
n.—nucleus.
vac.—vacuole.

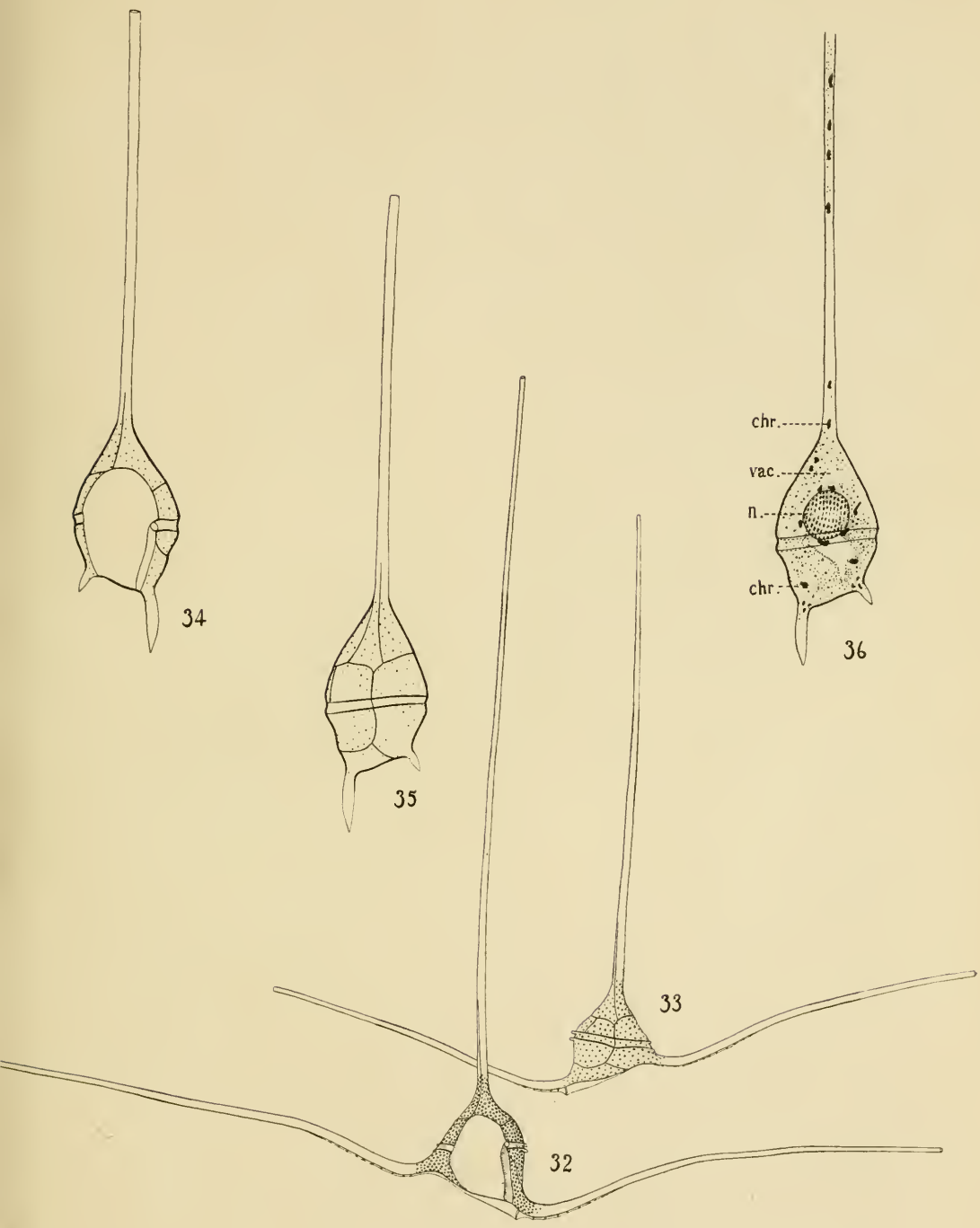
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PLATE XXX.

Fig. 37. Ventral view of *Gonyaulax pacifica*, sp. nov. × 533.

Fig. 38. Left face of same. × 533.

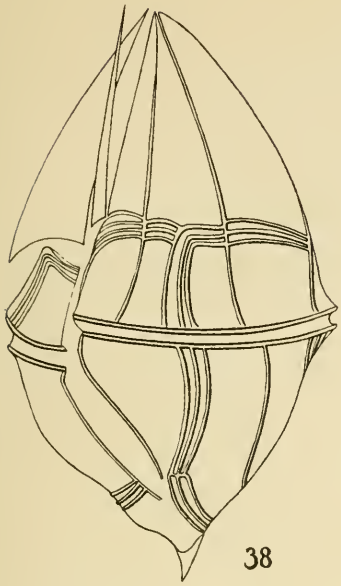
Fig. 39. Dorsal view of same. × 533.

Fig. 40. Dorsal view of *Peridinium multistriatum*, sp. nov. × 666.

Fig. 41. Ventral view of same. × 666.

ABBREVIATIONS.

ant.pl.—antapical plate.
ap.pl.—apical plate.
pr.pl.—precingular plate.
po.pl.—postcingular plate.



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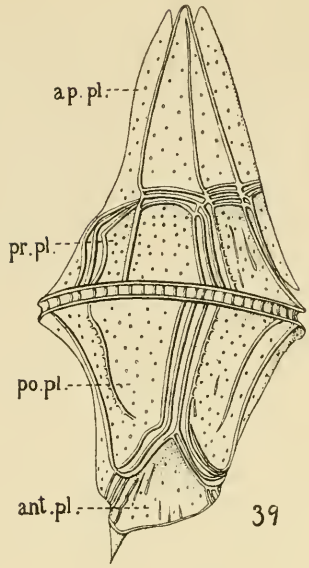

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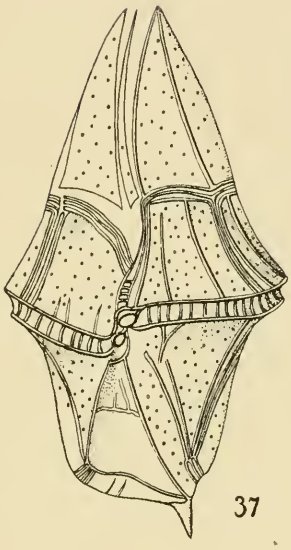

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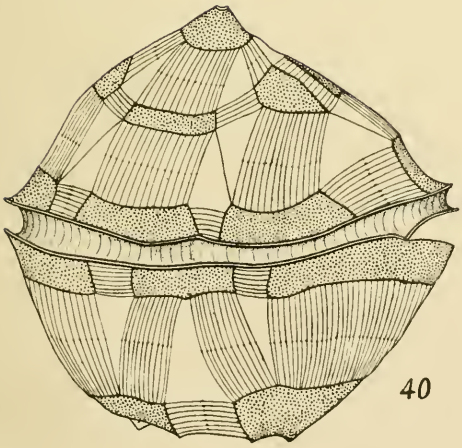

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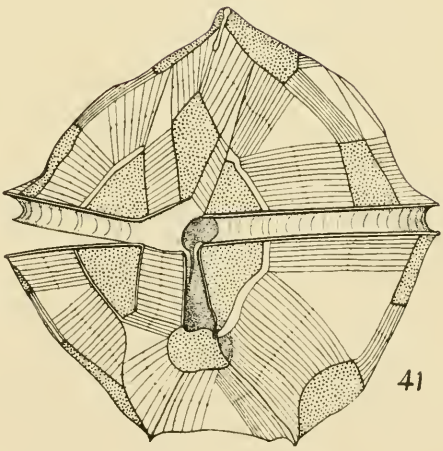

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PLATE XXXI.

Fig. 42. Dorsal view of *Peridinium minutum*, sp. nov. × 1120.

Fig. 43. Ventral view of same. × 1120.

Fig. 44. Lateral view of same. × 1120.

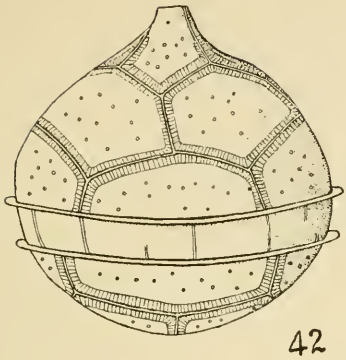
Fig. 45. Diagrammatic outline of epithecal plates of same. × 1120.

Fig. 46. Ventral view of *Peridinium crassipes*, sp. nov. × 736.

Fig. 47. Postero-dorsal view of same. × 736.

ABBREVIATIONS.

ap.pl.—apical plate.
int.pl.—intercalary plates.
pr.pl.—precingular plates.



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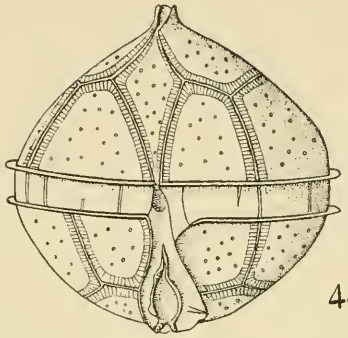

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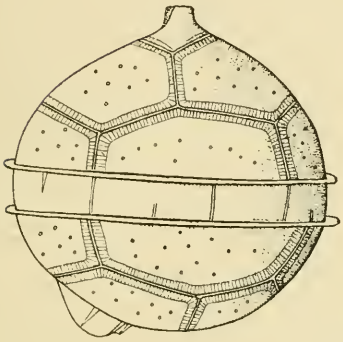

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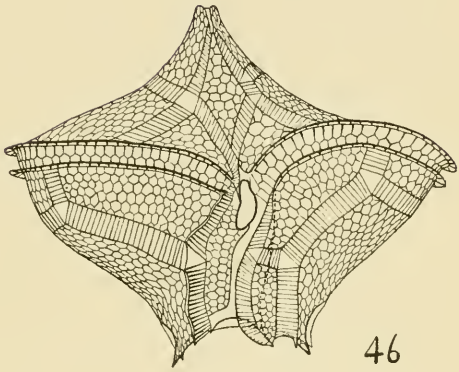

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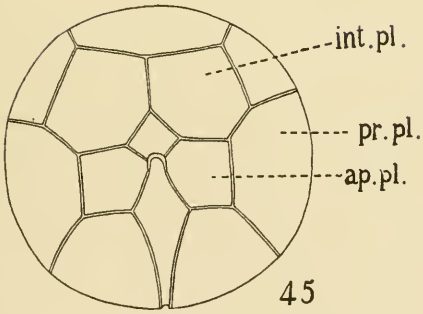

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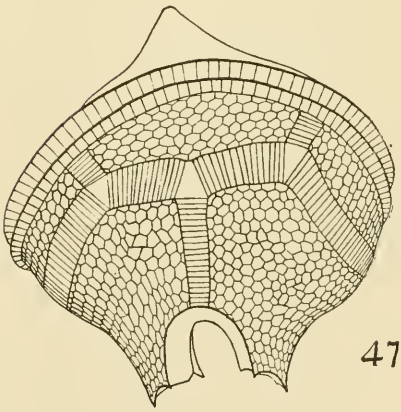

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PLATE XXXII.

Fig. 48. Ventral view of *Peridinium rectum*, sp. nov. × 500.

Fig. 49. Dorsal view of another individual of the same. × 500.

Fig. 50. Ventral view of *Amphidoma biconica*, sp. nov. × 750.

Fig. 51. Cell contents of same. × 750.

Fig. 52. Skeletal inclusions of same. × 1650.

Fig. 53. View of right side of *Amphisolenia spinulosa*, sp. nov. × 168.

Fig. 54. Same, view of anterior end. × 1095.

Fig. 55. Optical section of antapical region of same. × 1095.

ABBREVIATIONS.

chr.—chromatophores.
fl.p.—flagellar pore.
hd.—head.
n.—nucleus.
nk.—neck.
pl.—plasma.
s.sp.—suture spine.
vac.—vacuole.

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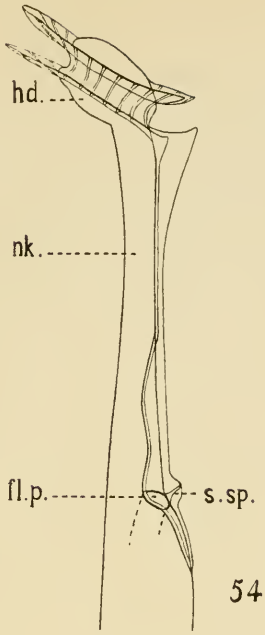
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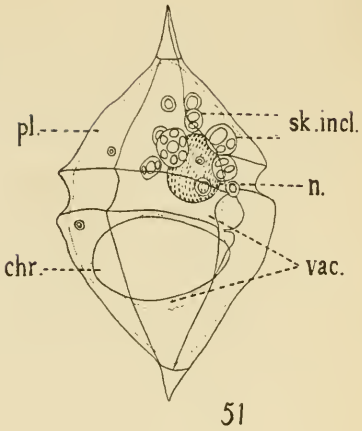
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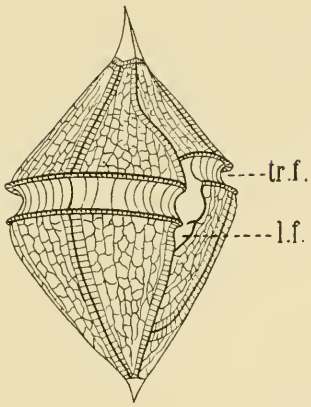
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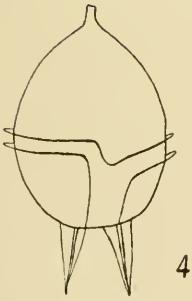
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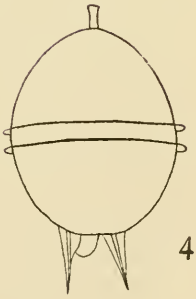

49

PLATE XXXIII.

Fig. 56. View of right face of *Dinophysis ellipsoides*, sp. nov. × 1020.

Fig. 57. View of right face of *Dinophysis diegensis*, sp. nov. × 638.

Fig. 58. View of right face of *Dinophysis diegensis*, sp. nov. forma *curvata*, f. nov. × 1028.

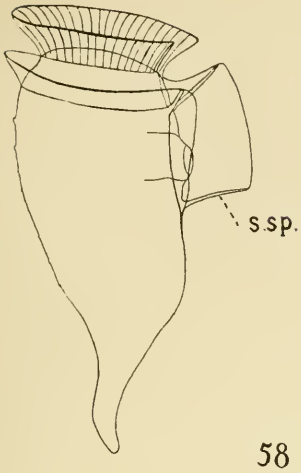
Fig. 59. Dorsal view of *Dinophysis diegensis*, sp. nov. × 638.

Fig. 60. Ventral view of same. × 638.

Fig. 61. View of right face of same showing different form of antapex. × 505.

ABBREVIATIONS.

fl.p.—flagellar pore.
l.f.—longitudinal furrow.
s.sp.—suture spine.



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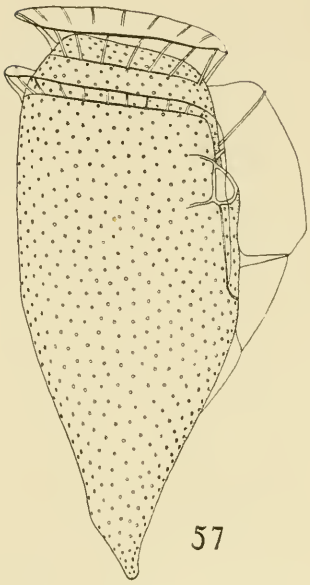

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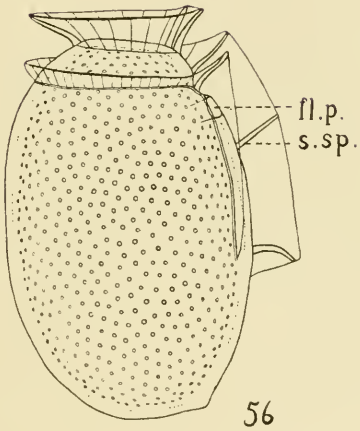

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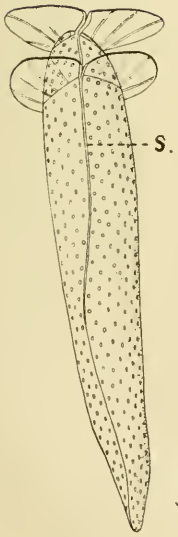

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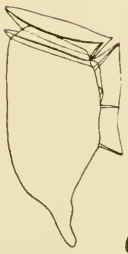

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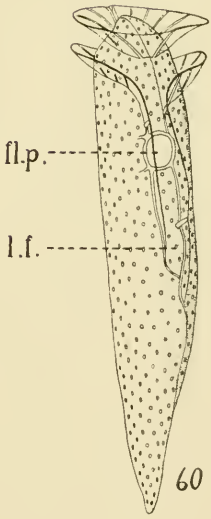

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ZOOLOGY
Vol. 3, No. 14, pp. 343-368, Plate 34, 21 text-figures. September 28, 1907

THE STRUCTURE AND MOVEMENTS OF *CONDYLOSTOMA PATENS*

BY
JOHN F. BOVARD

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ZOOLOGY

Vol. 3, No. 14, pp. 343-368, Pl. 34, 21 text figures. September 28, 1907

THE STRUCTURE AND MOVEMENTS OF *CONDYLOSTOMA PATENS**†

BY

JOHN F. BOVARD.

Condylostoma is one of the largest of the unicellular animals, and for this reason was chosen for a series of experiments which had for their object the correlation of body form and movements. This has already been done for *Paramaecium*, *Loxodes*, and other ciliates and flagellates; also for *Anuraea*. (Jennings, :04.)

The material was obtained from the shallow sloughs along the shores of Oakland, California. Those pools, which were filled only once or twice a month by the high tides and which became more or less stagnant, were found to be the best collecting places. The pools were dredged with a plankton net of No. 20 bolting cloth. Considerable zoogloea and half decomposed sea-weed were of necessity taken into the net. The animals were found in this mass of zoogloea and debris. Occasionally a few animals were taken from the surface of the water.

This paper will give, first, a brief review of the ectoplasmic structures of some of the largest ciliates; second, a discussion of the locomotor movements of *Condylostoma patens;* and third, an account of the motor reaction showing the relation of the form of the body to the movement.

The work was done at the University of California during the year 1905-06 under the supervision of Professor C. A. Kofoid, to whom I wish to express my sincere appreciation for kindly suggestions and help.

* Cited as Univ. Calif. Publ. Zool., Vol. 3, No. 14.

† A thesis submitted in partial satisfaction of the requirement of the degree of M.S. in the University of California.

STRUCTURE.

It is the intention in the following account of the structure to touch only on those points that will be used later in the discussion of movements. For more details relative to the ciliary and ectoplasmic structures, reference is made to Maier (:03) and Schuberg (:05). Throughout this part of the work I have followed the methods of Maier and have also used his terminology. He did not include *Condylostoma* in his investigations, but the elements of structure of this species are essentially the same in many respects as in *Stentor, Spirostomum,* and *Stylonychia.*

General Description.—The body of the animal is compressed dorso-ventrally, and very much elongated, the length usually exceeding the width seven times. The animals vary in length from 400 to 900μ, the average size being from 500 to 600μ. These dimensions are somewhat larger than those given by Stein ('73), (376–564μ), or Maupas ('83), (305–495μ).

The shape of the body is quite variable, depending on the number of food vacuoles present. The widest part is near the middle, the body tapering quite markedly toward the posterior tip, where it ends in a blunt point. The posterior end is not flattened as much as the rest of the body, but is set off somewhat by a sharp bend to the left and slightly ventrad. Near the anterior end there is a slight constriction on the left side. Forward of this point the width of the anterior end is variable, due to the flexibility of the left oral lip of the buccal groove. The whole body is somewhat bent, due to the curvature of the posterior part and the spreading of the left lip of the adoral zone, thus bringing the concave side to the left. The surfaces are easily recognizable as dorsal and ventral, the latter containing a large buccal groove. The shape of the animal has been described in a variety of ways. Stein ('73) has figured it with a long slender body of about the same width in all its parts. The buccal groove on the ventral surface is small, coming to a blunt point at the posterior end. Maupas ('83) in figuring the same species shows the tapering of the body, but makes it somewhat spindle shaped, thereby emphasizing too much the narrowness of the anterior end. His figure shows more nearly the real proportions of the buccal

groove, and is more accurate than Stein's, for it was made from a quiescent individual and not from one flattened under the cover glass. Bütschli ('89) has followed Stein, so his figures continue the same erroneous presentation of the form.

The variation of the figures is easily explained, for I have found that the amount of food present and the density of the water have much to do with the shape of the animal. Those that are well extended and full of vacuoles lose to a considerable extent the tapering form of the body and become "beutelförmig" (Bütschli) or "walzenformig" (Stein). Well-fed individuals prior to division become greatly elongated, and as the food vacuoles fill out the posterior tip, the body may become "beutelförmig" and look a great deal like Stein's figures except in the matter of the size of the buccal groove. Animals that are not full of vacuoles but are otherwise in a normal condition show invariably the tapering of the body toward the posterior end and the strongly curved posterior tip.

ECTOPLASMIC STRUCTURES.

Pellicula.—The entire animal is covered with a thin transparent homogeneous membrane. This is very elastic and allows of the freest movement, but still preserves the external form. It is thinnest over the middle parts of the body and thickens considerably toward the posterior end. Maupas ('83) calculates that the thickness varies from 2 to 4μ, while Bütschli ('89) believes that it may reach 8μ. By some it is claimed that this layer shows transverse striation and markings of various kinds. In *Condylostoma* there is no regular pattern and the modifications of the pellicula proper are exceedingly variable and not always visible. In the living animal this membrane is very transparent and recognized only when the animal bends sharply, making a fold in its side. In sections the pellicula appears as a thin non-staining homogeneous layer outside of all the other structures.

Surface Markings.—The surface of the body is marked by primary ridges which run the entire length of the animal. These mark the position of the myonemes. The space between the primary ridges is divided into many small polygonal areas

by secondary ridges one-half the height of the primary. These are ectoplasmic structures and disappear when the animals are treated with killing and fixing reagents. There is but a single row of the polygonal areas between the primary ridges at the anterior end of the animal. At the middle where these ridges are farthest apart there is a double row of these areas, and at the posterior end there is but a single row owing to the proximity of the myonemes. These small irregular areas contain the trichocysts. (Pl. 34, fig. 1.)

Myonemes.—While *Condylostoma* is a highly contractile form, it does not possess this property to the same degree that *Stentor* or *Spirostomum* does. Engelmann ('75) has shown that the entire ectoplasm of *Stentor* is anisotropic and therefore contractile. In the ectoplasm of *Stentor* there are hyaline threads which run lengthwise of the body. These have been definitely correlated with the contractions of the animal and have been called myonemes by Bütschli ('89). These same structures are found in *Condylostoma.* If an individual is compressed strongly under the cover glass, the contractions and expansions of these fibers may be followed.

The myoneme runs from the extreme posterior tip to the anterior end of the animal. Each fiber is continuous and does not show branching as in *Stentor* and *Spirostomum.* Schuberg ('86) in his work on *Stentor* calls attention to the ramification zone located near the posterior end of the animal, in which the myonemes are few, but give rise to many fibers by branching. No such zone can be distinguished in *Condylostoma*, each fiber being continuous from one end to the other. The fiber begins at the extreme end of the posterior tip and runs to the anterior end. Other fibers are interpolated between these, but never show any connection with them by means of branching as in *Stentor.* The fibers follow the rows of cilia and give the animal a longitudinally striped appearance. In normal individuals the myonemes are closest together at the posterior end and farthest apart at the middle. On the ventral surface, as the fibers proceed anteriorly they separate at the posterior end of the buccal groove and continue to its anterior margin. None of the fibers end on the lateral margin of the buccal groove.

The relation which the *myonemes* bear to the cilia is quite different from that found in some other ciliates. In *Stentor* the myonemes lie just below the basal bodies of the cilia, as shown by Johnson ('93) and Neresheimer (:03). It is clear, on surface view, that the cilia in *Condylostoma* are to one side and not directly above the myonemes; the displacement is not very great but sufficient to remove all doubt as to the exact location of these elements. The myonemes form the primary ridges which mark the surface and the cilia follow the furrows at the side of these (Pl. 34, figs. 1 and 2). In transverse sections the basal bodies of the cilia are always below and to one side of the myoneme.

The myonemes have the typical structure found in Heterotricha. They are long threads which are oval in transverse sections and lie in small canals. It is almost impossible to make out these canals in sections, but when a part of the ectoplasm is seen in surface view, on either side of the deeply staining myoneme is a very clear area. This area would correspond to the "Zwischenstreifen" as seen in *Stentor*. Bütschli ('89) shows the relation of myoneme and canal where the canal is of large size. This is true for *Holophrya discolor* as well as *Stentor coeruleus*. In these animals the myonemes are decidedly oval according to Bütschli ('89) and Neresheimer (:03); but Johnson ('93), (Pl. 23, fig. 5), however, speaks of them as round and so figures them. Neresheimer places the long axis of the oval perpendicular to the surface, while Bütschli places it parallel to the surface. The myonemes in *Condylostoma* are only slightly oval in section, the long axis being perpendicular to the surface. No cross striations have been observed in the myonemes of *Condylostoma*, although they have been reported in other ciliates by Lang (:01) and Neresheimer (:03).

Cilia.—Cilia are found all over the body with the exception of the surface of the buccal funnel. They are arranged in rows which follow the course of the myonemes and arise from furrows which lie along the sides of the myonemes. These lines of cilia run longitudinally when the animal is resting on the bottom of the aquarium, but when it is swimming run spirally around it from right over to left. This change in the direction of the lines of cilia is correlated with the change in the form of the body

which takes place when the animal begins to swim. The basal bodies of the cilia are located in the ectoplasm and at a point below and to one side of the level of the myoneme. Maier (:03) has described in *Spirostomum* two kinds of cilia, those which taper to a point and those that are hair-like having the same dimensions throughout. The cilia of the surface of the body of *Condylostoma* fall under the latter class, being very long slender filaments. They vary but little in length, those on the posterior end being the longest. At this point they are arranged as a small tuft and exhibit but little motion. As the animal glides over a surface that is covered with minute debris, a great deal of it catches in this tuft of posterior cilia. Maupas ('83) has called attention to the difference between the distribution of the dorsal and ventral cilia, those on the ventral surface being the longest and fewest in number. As far as my evidence goes the dorsal and ventral cilia are not differentiated either in structure or number.

Membranellae.—Such a complete account of the membranellae has been given by Maier (:03) that I shall only attempt to give some of the characters as they appear in *Condylostoma.* The membranellae have the appearance of large cilia as they are rapidly beating. When the animals are compressed and slowed down by the gelatin method, the ciliary appearance is lost and they resemble fan-like organs. They are found along the anterior edge of the buccal groove and down the left lip of the peristome, down into the gullet around which they wind spirally. Those of the anterior edge are the largest, the size gradually diminishing toward the posterior end. The position of those on the left lip is such that the stroke is entirely within the gullet. Those of the anterior edge beat in such a fashion that particles are impelled to the left side. Each of these fan-like organs is made up of a double row of fibers, each ending in a basal body (Pl. 34, fig. 6). The double row is only seen when the organ is viewed from the side. The basal bodies lie embedded in the ectoplasm and form a row at right angles to the direction of the stroke of the organ. Around the bases of these bodies the ectoplasm thickens and forms a more or less well defined plate extending down into the endoplasm. This plate is called "Basal-

wulst'' by Maier (:03), (*Bl.* Pl. 4, fig. 10 b). It is three cornered, the lower corner terminating in a fiber which connects together the ''Basalwulsten'' as shown in Pl. 34, fig. 5 (Maier, Ef. Pl. 4, fig. 10 b). This end fiber is supposed to be contractile, but not in any way connected with the myonemes of the body. Others have supposed that this end fiber must have some nervous function such as coördination of movement because it connected the ''Basalwulsten'' one to the other (Maier :03, Pl. 4, fig. 10 c).

The membranellae are regarded as a fusion of many rows of cilia. The fact that the buccal cavity is entirely without cilia has led to the suggestion that the cilia have migrated from this area to the edge and here become cemented together, forming a series of broad fan-like organs.

Undulating Membrane.—This is a broad thin transparent membrane which lies in the buccal groove and is attached at the base of the right oral lip. The breadth of the membrane is such that it will reach clear across the peristome field when the left lip is not extended so that the buccal groove becomes a funnel with the small end leading into the mouth.

In living animals the membrane appears as a more or less homogenous structure traversed at intervals by fibers. In sections the membrane appears to be made up of many fibers, each ending in a large basal body located in the ectoplasm (Pl. 34, fig. 7-8). These fibers run the full width of the membrane and are very close together. Maier (:03) suggests that the membrane was formed by the fusion of a single line of cilia, the cementing substance between the cilia forming a continuous membrane. The basal bodies or ''Basalsaum'' lie in the angle which the right oral lip makes with the adoral zone so that on the ventral side the right lip protects the basal part of the membrane. Pl. 34, fig. 7, shows the position of membrane, but owing to the contraction of the protoplasm the right lip has become a thick rounded mass. The membrane is broadest at the anterior end, ending quite abruptly before it reaches the gullet.

Buccal Groove.—At the anterior end on the ventral side of the animal is a three-cornered peristome formed by the edges of the two lips of the adoral zone. The buccal groove differs quite a good deal from the flattened groove of *Paramaecium* and

resembles more the deep pocket-like cavity of *Bursaria truncatella.* The cavity is very much greater than is indicated by the size of the triangular space on the ventral surface, for it is not only wider, extending under the right adoral lip, but it is much longer, extending down into the protoplasm as a large sac from the left corner of which the short gullet arises. Bütschli ('89) describes the right lip as lamella-like, bending around to form a distinct angle and extending to the median line, while the left lip is placed so that the peristome is wide open but can be changed by the contraction of the left side of the adoral zone. The buccal incision is widest at the anterior end and narrowest posteriorly. The opening between the right and left lip is variable and depends on the state of contraction, for at times the groove is wide open and at others the margins are closely approximated. The relation of the length of peristome to the length of the animal is also a variable quantity. Bütschli ('89) says the peristome is one-quarter or less of the length of the body. The surface of the groove is entirely free from cilia, but on the outer edge certain structures are found which compensate for the absence of cilia. Along the right side and emerging from the angle formed by the right lip and adoral zone is the undulating membrane, and along the anterior edge and down the left lip of the buccal incision extending down into the gullet are the membranellae.

LOCOMOTOR MOVEMENTS.

I. GLIDING.

The animals spend most of the time on the floor or sides of the aquarium and in the field are found most frequently on the bottom of the sloughs amongst the zooglea. The bacteria grow rapidly and cover the bottom of the dish, forming a scum or coat, over which the animals may be seen to glide in large numbers, very few swimming freely in the water.

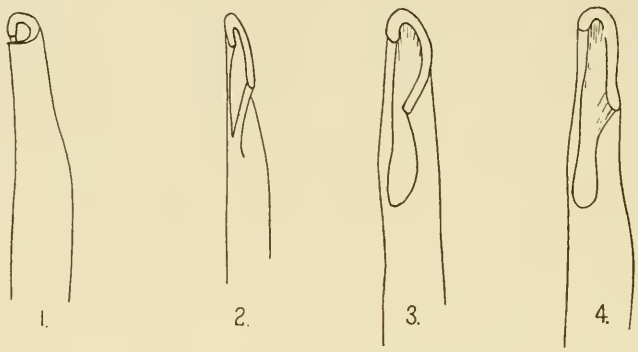
Gliding is a slow movement, interrupted with frequent stops. It usually occurs on the bottom of the aquarium, more rarely on the sides and surface film. It is the most common method of locomotion, partly because of the specific gravity of the animal,

but more important is the fact that food is more abundant on the bottom. Gliding is always executed in the same manner, a structurally defined side being always next to the sub-stratum. Gliding is thus set off from the movement in swimming, and cannot be classed as a chance movement.

Parts of the Body Concerned.—During gliding the cilia all over the body beat, but those of the dorsal surface less strongly than when swimming. When India ink is added to the water containing the animals, the exact actions of the cilia are more easily made out. In many cases the cilia on the dorsal surface are seen to beat but slowly and those of the posterior tip at irregular intervals. At times the cilia have a peculiar waving motion, apparently beating first in one direction and then in another; on other occasions they do not beat at all. This is especially true of those individuals which keep the posterior tip normally very close to the surface film. The body cilia, while the principal factor in causing this gliding, are not the only means, for it is certain that the membranellae play some part. The action of this set of organs is as follows: the stout fan-like membranellae by their vigorous backward stroke cause strong currents to pass down the buccal groove and out on the left side, through the arch formed by the raised portion of the left lip of the adoral zone. Some idea of the force of this vortex that is constantly passing posteriorly can be obtained by observing the force with which particles pass in and out through the groove. On one occasion one of these animals happened to strike another and remained for a moment or two holding on to it by the suction of the buccal groove. At the instant of release a distinct evagination of the cuticle of the attacked animal could be plainly seen. The posterior end of the animal which plays such an important part in the motor reaction is also important in governing the direction of gliding.

Position of the Body.—During this movement the anterior end of the animal presents numerous changes. The whole adoral zone is depressed so that the anterior margin of the buccal groove comes close to the substratum. The right lip usually varies but little, holding its place close to the bottom while the left lip may or may not be held in such close contact with the substratum.

Figs. 1, 2, 3, 4 show the various positions assumed by this part of the adoral zone. Fig. 1 shows the anterior edge closely applied, a position usually assumed at the commencement of the gliding, later the anterior corner of the left lip raises as in fig. 2, this continues and as the motion increases an arch is formed as shown in fig. 3, through which the water from the buccal funnel escapes. The left lip continues to elevate itself by a twisting of



Figs. 1, 2, 3, 4.—Positions assumed by the left adoral lip during gliding.

the whole anterior end until on the left side the buccal funnel is exposed (fig. 4). The animal is now usually traveling in a path which is a circle with the buccal groove facing inward. The body of the animal remains with the ventral surface applied closely to the bottom, except for a film of water sufficient to allow for the play of the cilia. At times, when the animal is making small circles to the left and the left lip is much elevated, the animal turns on its right side, so that the buccal funnel is completely exposed.

The posterior end plays an important part in the direction of gliding. The bending of the posterior end towards the left gives to the animal a curvature which is responsible to a large extent for the direction of movement. This end is extremely flexible, a noticeable feature of the backward movement, when it folds under and to the left. It also acts as a rudder for the forward movement, for the path described usually has the same curvature as is shown by the shape of the body. The posterior tip is more

closely applied to the bottom than any other part, giving the appearance of dragging.

There is some difference between gliding on the bottom and on the surface film. In the first case, the entire body is in close relation to the substratum; in the second, only a small part actually comes in contact with the film (figs. 5 and 6). In this case, only the adoral zone touches the film and the rest of the body sinks away, suggesting that the body was so heavy that it could

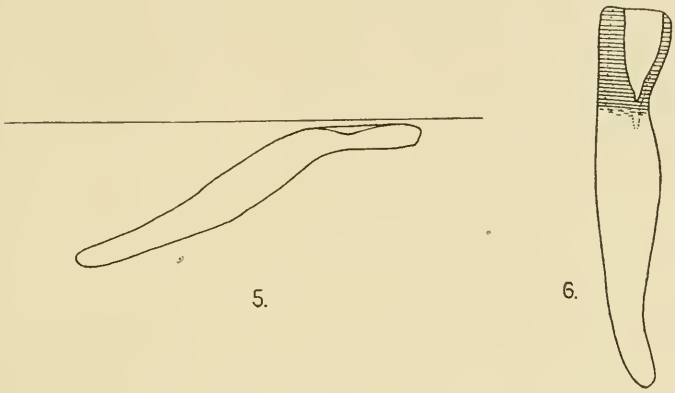


Fig. 5.—An animal gliding on the surface film.

Fig. 6.—The shaded portion is that which is in actual contact with the surface film.

not hold itself in a horizontal position on the film. The right and left lips are close to the surface, while the dorsal part of the adoral zone is well arched to form as large a funnel as possible. In movement on the surface film the spreading of the lips which appears in gliding on the bottom is absent. Practically all the cilia enter into this movement, those of the dorsal surface beat as well as those of the ventral surface. The ciliary action shows waves of contraction. These appear to run just in the opposite direction to the beat of the cilia, so that this forms a means of determining the direction of the beat of the cilia. Concerning the action of the cilia during this movement it is sufficient to say that all are concerned, those of the dorsal surface beat forwards and reverse at the same time as those on the remainder of the

body, except that the beat may not be as strong. The membranellae are different in their action, reversal usually being but momentary. An effort was made to determine whether the beat of the membranellae was independent of the beat of the body cilia. As a rule, reversal of the membranellae is accompanied by a reversal of body cilia, especially during a change of direction or when the motor reaction is given. The exceptions to this are seen when the animals are traveling through a fairly clear field. A reversal of the membranellae may occur, sufficient for the ejection of particles without any stop or reversal of the movement of the animal. The same is true of animals motionless on the bottom of an aquarium, when the membranellae may reverse again and again without any movement on the part of the animal. Again during the motor reaction after the first reversal of both the membranellae and cilia, the former resume their backward beat while the cilia continue their reversed action for some time.

That the membranellae must be largely responsible for the gliding movement is indicated by the fact that when on the surface film often the only part close enough to the film to be able to act on it is the buccal groove with its fringe of membranellae, while the rest of the animal hangs down freely. Of course, the body cilia must have some effect, but owing to the fact that the buccal groove is held so close to the film that the body does not rotate as in swimming, and that the direction of the movement is to the right instead of to the left as in gliding on the substratum and just opposite to the beat of the membranellae, it cannot be doubted that these organs play a considerable part in the animal's movement.

Rate of Gliding.—The rate of gliding is fairly constant under normal conditions. Animals on the surface film have a faster rate than those on the bottom of an aquarium. Measurements of the time required for the animals to travel 1 mm. showed that the distance is covered in about 2.9 seconds. The rate of movement changes considerably when the animals are stimulated, apparently increasing to two or three times the ordinary rate. The increase in rate on the surface film may be correlated with the fact that the body of the animal is not in contact with the film, and the cilia beat faster, as is the case when swimming.

Direction of Gliding.—The direction of gliding is usually forward, with occasional movements backward as seen in the motor reaction. Only under extraordinary conditions is the movement in a straight line, the usual course being the arc of a circle whose center lies to the left of the animal. The shape of the animal would cause such a direction on account of the curvature of the body.

Although not the normal direction, the animals may be observed occasionally to move in circles *to the right.* Animals that have been disturbed by moving from one aquarium to another show this latter movement beautifully. By sudden jerking of the anterior end to the right they move toward that side. All the movements are quick and erratic for a considerable time, till they become accustomed to their surroundings. Gradually the rapid movements slow down and the normal movement to the left is observed. In other cases the whole anterior end may be bent to the right (see fig. 12), but such a condition is usually of very short duration.

Direction of Movement in Cut Pieces.—The form of the body of Condylostoma determines the direction of its movement. This is clearly demonstrated in the locomotion of cut pieces when the animal is transected. The direction is normally to the left and the posterior end of the animal is bent to the left. Is there any correlation between these two facts? If the posterior end is responsible for this direction, then removal of this ought to result in a different direction of gliding. The cut was made as in fig. 7 and the movements of piece *A* watched. This piece is now straight and with the posterior end removed shows no bending of the body towards the left. This piece did not turn towards the left but took a straight course. Again how will the posterior piece behave when the anterior part is gone? Piece B, fig. 8, moved forward, always swerving to the left just as the normal individuals do. This shows that the direction of gliding is dependent on the form of the animal and particularly on that of the posterior tip. If the movements of the anterior piece (piece A, fig. 8) are watched, it will be noticed to be moving in circles to the right and duplicating the conditions on the surface film. By reason of the cut only the anterior end of the animal reacts on

the substratum, the membranellae are now the strongest factors for locomotion and consequently influence the reaction. When the anterior end is reduced in size to that of piece A, fig. 9, it describes smaller circles than when the piece is larger (piece A, fig. 8) showing that the membranellae have a relatively greater influence when the directive effect of the posterior end is lost.

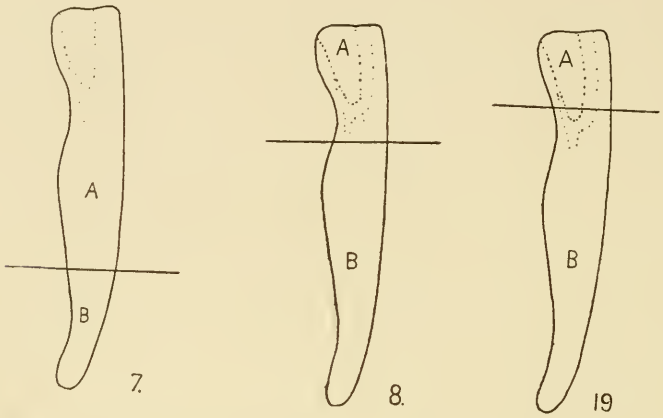


Fig. 7.—During gliding Piece A pursued a straight course.

Fig. 8.—During gliding Piece B pursued a curved path as normal individuals do.

Fig. 9.—Piece A is smaller than Piece A, fig. 8, and shows more deviation to the right.

Summary.—During the gliding movement the anterior end is depressed, the left lip is extended and the buccal groove exposed on the left side. The entire ventral surface is close to the bottom with the exception that in movement on the surface film the adoral zone is the only part in actual contact. The posterior end is bent towards the left and held very close to the bottom, giving the appearance of dragging. The membranellae together with the cilia are the organs of locomotion. Gliding on the surface film is faster than on the bottom of the aquarium. The direction of the gliding is dependent on the shape of the body. The bending of the posterior end toward the left acts as a rudder and causes the animal to turn towards the left.

II. SWIMMING.

Far less than one-half the time is given over to swimming. *Condylostoma* shares with *Bursaria* the disposition to spend most of its time on the bottom of the aquarium. This seems to be characteristic of many of the larger ciliates, *Spirostomum, Loxodes, Lionotus, Bursaria,* of which many are found in the waters with *Condylostoma.* They all show the tendency to swim in a spiral when stimulated sufficiently to cause them to leave the substratum.

The mechanism and significance of the spiral swimming amongst swarm spores, flagellates, ciliates, and rotifiers has been thoroughly gone over in Jennings' work on Animal Behavior ('99 and :04).

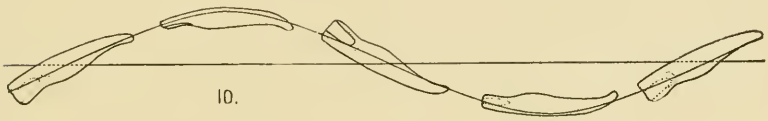


Fig. 10.—The various phases exhibited by an animal during swimming as seen from above.

As the animal moves through the water it will be noticed that it is revolving on its long axis, the body swerving and not pursuing a straight course. Closer analysis will show that this movement is in a spiral which varies considerably with different individuals. If we should see the animal swimming towards us, the anterior end would seem to describe a circle turning in the same direction as the hands of a clock. It would be also noticed that this end was always orientated in the same way, the concave side of the adoral zone always facing the inner side of the circle. Applying this now to the movement, we have the animals swimming in a spiral with the buccal groove always facing the inside of the spiral, which is the case in other ciliates, *Loxodes* and *Paramaecium* for example. See Jennings (:04).

The rotation of the animal while following this spiral is the same as for *Paramaecium*, that is, while the animal is moving away from the observer, the upper surface is constantly moving to its left. Fig. 10 illustrates the different phases that the animal

would exhibit, were it watched from above. The movement may be defined as follows: down, right, up, left, and so on. This constant turning causes the animal to continually change its direction so that its course continues in a fairly straight line. As Jennings ('99) has pointed out, the real significance of this spiral swimming is that it keeps the animals moving in a straight line when the asymmetry of the body would tend to make it move otherwise.

In *Condylostoma* this movement is directly correlated with the structure of the animal. Starting with dorsal side uppermost, movement forward causes a turning to the left, because of the bend in the posterior end to the left and also downward because of the ventral trend of tip. The combination of these movements tends to rotate the animal on its long axis, so that when the extreme downward position is reached the animal has its ventral surface uppermost. In this position the curvature of the posterior tip is to the right and up, which causes the body to turn to the right and up. The body continues to rotate until it is again dorsal side uppermost.

In *Paramaecium*, there are three possible factors that determine this spiral movement: (1) The oblique stroke of the cilia, (2) the oblique position of the peristome, (3) the asymmetrical form of the body (Jennings '99). These factors are also applicable to *Condylostoma*. Concerning the first, the oblique stroke of the cilia, it is very possible that such action could produce the movement. The cilia are placed in straight rows which run lengthwise of the animal and not obliquely around it when the animal is not swimming. When the animal is swimming, however, the decurved nature of the posterior end causes the rows of cilia to become somewhat oblique and so would tend to rotate the animal. The second factor, the oblique position of the peristome, is not operative in this species, for the animal moves in a direction directly opposite to that which the oblique position of the peristome would bring about. Whether the third of these factors, the asymmetrical form of the body, has any weight depends on whether the form of the body is a result of the motion or not. That it is not the result of the motion is seen upon observing the shape of the body when the animal is gliding or when it is lying close to the substratum.

lying close to the substratum. The posterior end is curved to the left and closer to the substratum than the rest of the body. During the motor reaction in the backward movement this end is turned sharply to the left and often folded underneath, so that it is hard to believe that the shape of the body while swimming is any other than a natural one. This being the case, the spiral swimming can easily be explained as a result of the form of the body. The peculiarly curved end acts as a rudder and constantly turns the animal from the straight path, just as it does in the simpler gliding movement. This seems to be the most important factor of the three in a determination of the spiral swimming in *Condylostoma.*

In swimming the rate of movement is more rapid than in gliding. This conclusion is based on careful estimates rather than on accurate measurements. The rate of movement in gliding is slower than in swimming, for it is during this time that the animals are feeding. The friction with the substratum also prevents rapid movement.

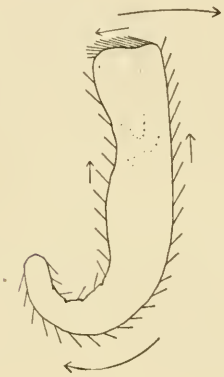
III. MOTOR REACTION.

Jennings ('04) has found that the essential features of the motor reaction are the same for each of the organisms which he studied. It is the intention to give some facts which will show that *Condylostoma* acts as do other *Protozoa* in its general movement but that the mechanism by which this action is produced presents some distinctive features in this species.

Of the two locomotor movements, swimming and gliding, the latter is by far the most common, accordingly it is during this method of locomotion that the motor reaction can be best shown. While in the gliding position, the ventral side is close to the substratum, the buccal groove faces toward the left and downward, and the posterior end is bent somewhat toward the left. Whenever an obstruction is encountered, the animal immediately stops, backs up, turns to the right and then proceeds in a new direction which generally will carry it past the source of stimulus. The movements of *C. patens* are not rapid and are easily followed with the low power of the microscope owing to the large

size of the animal. Throughout the experimental work a Zeiss-Greenough stereoscopic microscope was used and proved to be an invaluable instrument for this kind of work.

As soon as the animal meets an obstruction all the cilia reverse, and at the same time there is a contraction of the myoneme fibers on the left side and a bending of the posterior end sharply to the left. As the backward movement proceeds the posterior end in its curved position acts like the rudder of a ship. Its resistance to the water and its curvature cause the animal to take a curved path, which if continued far enough would describe a circle. The bending of the posterior end of the body is always to the left and never in any other direction, except while swimming when it is directed to the left and slightly ventrad.



11.

12.

Fig. 11.—An animal executing the backward movement of the motor reaction. The small arrows show the direction of stroke of the body cilia, the large arrows the resultant movement of the body.

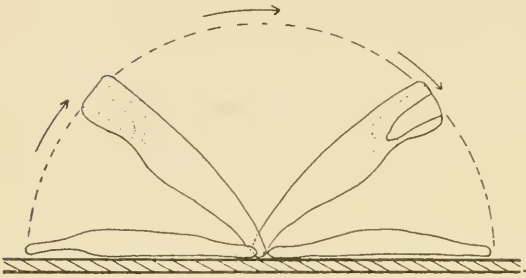
Fig. 12.—The bending of the anterior end to the right at the end of the motor reaction.

Fig. 11 illustrates the part the body plays in this reaction. This is a typical case where the whole body is affected by the contraction of the myoneme, the posterior end being bent more than the rest. That this bending does play a most important part in the direction which the animal takes is shown by the fact that the path of movement follows the curvature of the body. This

is the most effective means for directing the anterior part away from the source of stimulus in the backward movement, the degree of efficiency depending on the arc of the circle completed. The body now returns to the normal form and the animal advances in a new direction. At this point there is often noticed a bending of the anterior end towards the right (fig. 12), due to a contraction of the myonemes on the right side.

The cilia at the moment of stimulation all reverse; this causes the quick dart backwards. The subsequent action depends on the strength of the stimulus. Under weak stimulus, the reversal of the cilia is but momentary; those of the left side may slow down, not beat at all, or beat slowly forwards. Those of the right side continue a vigorous beating forwards, as also do those of the dorsal surface. In cases of strong stimulus, all the cilia reverse and continue their forward stroke for some time. The cilia of the left side now begin to beat backwards, those of the right side continue beating forwards, the combined action turns the body towards the right, then those of the right side strike backwards, and the animal proceeds in the new direction. A careful search was made for the transverse beat of the cilia at the anterior end, which is such a prominent feature in *Paramaecium*, but no evidence was found to indicate that this is the case in *Condylostoma*. The gelatine method was used, which slowed down the movements and carmine was added to show the action of the cilia better. All observations, with a single exception, seem to point to the fact that the motions of the cilia were confined to a forward and backward movement. Certain movements which occur during gliding seem to indicate the transverse action of the cilia. Occasionally animals moving along the bottom of an aquarium stopped and elevated the anterior end. This action, at times, was continued till only the posterior tip was left in contact with the substratum (fig. 13). A further continuation caused the animal to turn completely over, the anterior end now pointing in an opposite direction to that held at the beginning of the movement. Sometimes after the anterior end had been elevated it began to swing to the right so that it described an arc of a circle (fig. 14). In this position the posterior end remained fixed. The new direction the animal took on settling down was

dependent on the length of the arc of the circle completed by the anterior end. Unfortunately these movements were not observed when India ink or carmine was in the water. While it would seem natural to suppose that the cilia at such times must beat transversely to raise the body, it can be said that in the other movements no case of the transverse stroke was noted, even under the most favorable circumstances.



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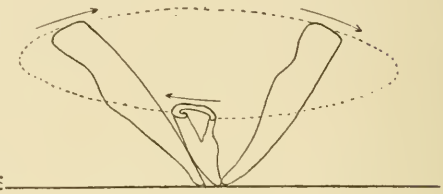


14.

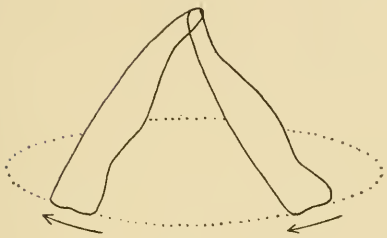
Fig. 13.—Occasional movements during gliding which probably call in the transverse action of the cilia.

Fig. 14.—Rotary movements during gliding which probably call in the trarsverse action of the cilia.

The membranellae play a considerable part in the motor reaction. The anterior edge of the adoral zone and the left lip of the buccal groove are lined by these organs. The normal beat of the membranellae is from right to left. At the moment of stimulation all the membranellae reverse their action; then those of the buccal groove resume their normal stroke beating slowly backward, and those of the anterior end also resume their normal beat from right to left. During the remainder of the action all the membranellae continue their normal beat. The membranellae of the buccal groove under strong stimulus may continue reversed for some time, but those of the anterior end never continue beyond the moment of contact, after which they resume their beat towards the left with increased vigor. This action tends to throw the anterior end to the right and thus aids in the execution of the motor reaction. The action resulting from the membranellae is illustrated by fig. 15. A large animal was

swimming downwards in an aquarium, and when the anterior end came in contact with the bottom, it spun around to the right without backing up while the posterior end was still elevated.

Attention is called to fig. 16 of a large individual swimming down towards the bottom of an aquarium clouded with India ink. As the animal struck the bottom it gave the motor reaction,



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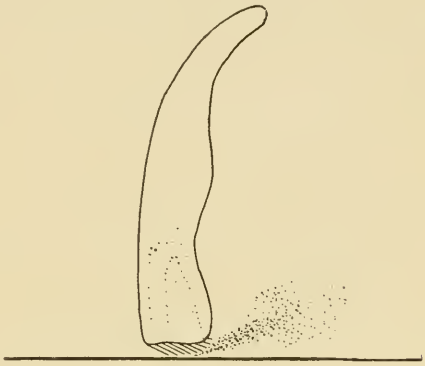


16.

Fig. 15.—The action of the membranellae causes the animal to swing to the right.

Fig. 16.—The particles of carbon thrown to the left by the action of the membranellae.

all body cilia reversed, and the membranellae increased their activity as shown by the force with which the carbon particles were thrown to one side. There was no transverse action of the body cilia in this case. During the backward movement and the pause just before moving forward again, the increased activity of the membranellae would have much to do with the turning of the animal toward the right.

To sum up, at the moment of stimulation the membranellae reverse and then resume again their normal beat, with the exception that those of the anterior end are more active. The cilia all reverse, producing a backward movement of the animal. Under a weak stimulus those of the left side may be reversed but a short time and resume their normal beat. The myonemes on the left side contract and produce a sharp curvature in the posterior end of the body which causes the animal to turn towards

the left. The cilia on the left side now beat strongly backwards. The action of the membranellae and the curvature of the body turn the animal so that it points in a new direction which is toward the right and away from the buccal groove. The cilia on the right side now beat backwards, and the animal proceeds in the new direction.

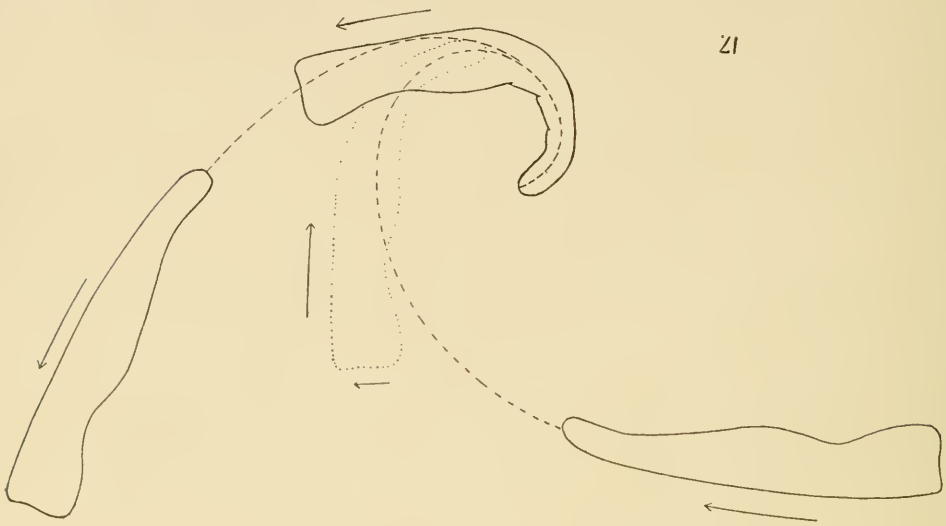


Fig. 17.—The various phases of the form of the body of the animal while executing a motor reaction.

IV. MOTOR REACTION IN CUT PIECES.

In order to further test the functions of the various parts of the body in the motor reaction the animals were cut in several pieces. The posterior tip of a large animal was removed (fig. 18). The piece A, on weak stimulus, gave a normal motor reaction except that the posterior end did not bend to the left. The body remained rigid and after moving backwards for a considerable distance the animal turned toward the aboral side, that is, toward the right as a result of the action of the membranellae as seen in fig. 19. Fig. 19 shows that the point about which the animal turns is not at the posterior end but near the middle of the animal.

In an individual which was cut into equal parts, the anterior end backed up but little, but prolonged the spinning about to the right before proceeding forward. In all cases where the posterior end was removed the anterior portion showed no tendency either at its posterior end or elsewhere to bend toward the left. Relatively more time was consumed in the turning part of the reaction by these anterior fragments than by normal individuals. The duration of the backward movement is correspondingly shortened in the former.

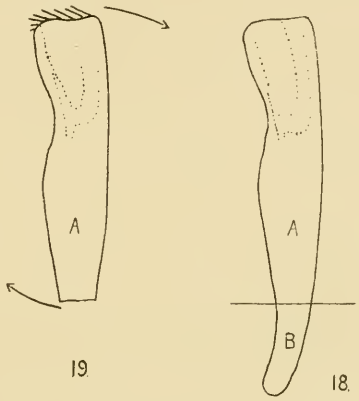
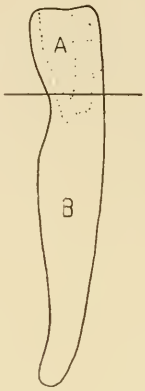


Fig. 18.—Piece A exhibited no bending of the body during the motor reaction.

Fig. 19.—Piece A executing the turning part of the motor reaction.

There is another factor here that must not be overlooked. In removing the posterior end we are losing the influence of its cilia. As the pieces of the anterior end are made smaller and smaller, we find that the backward movement becomes less and less extensive till, when it assumes the size indicated in fig. 20 A, a reversal of the cilia accomplishes nothing, and the piece reacts by simply turning to the right. The number of cilia are not sufficient to produce any pronounced movement while the increased activity of the membranellae is felt immediately and turns the animal to the right. Referring again to fig. 20, piece B gives the normal motor reaction, the posterior tip bending towards the left during the backward movement and the cilia giving their normal movements. The bending of the posterior tip accounts for the movement of the anterior end to the right.

The results, in the main, of the motor reactions in cut pieces are the same for the two parts as for whole individuals, showing first, a backward movement, a turning toward the right away from the oral side and then a movement forward. The means by which the reaction is accomplished differ in the two ends.



20.

Fig. 20.—Piece B exhibited the bending of the body during the backward movement of the motor reaction.

GENERAL SUMMARY.

The movements of *Condylostoma patens* are directly dependent on the shape of the body. Normally the animal moves in a circle to the left when gliding. This is caused by the bend of the posterior end of the body toward the left.

The spiral swimming is the result of the curvature of the body and not wholly dependent on the oblique position of the cilia.

The motor reaction is the same as for other Protozoa. It consists of a backward movement, a turning toward a structurally defined side and then a movement forward.

The motor reaction is of the same type in cut pieces as in whole individuals but modified by the form of the pieces.

Zoological Laboratory, University of California,
January 14, 1907.

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EXPLANATION OF PLATE.

PLATE XXXIV.

Fig. 1.—Sculpturing on the surface between the myonemes. × 1400.

Fig. 2.—Surface views showing the position of the myonemes. × 1400.

Fig. 3.—The distribution of the trichocysts in surface view. × 1400.

Fig. 4.—A section giving the position of the myonemes and the basal bodies. × 1400.

Fig. 5.—A section of the adoral zone showing the membranellae. × 875.

Fig. 6.—The membranellae in cross section. × 1075.

Fig. 7.—The undulating membrane in cross section. × 1075.

Fig. 8. The undulating membrane in oblique section. × 875.

LIST OF ABBREVIATIONS.

bb.—basal body.

Bw.—Basalwulst.

cl.—cilia.

Ef.—End fiber.

ml.—membranellae.

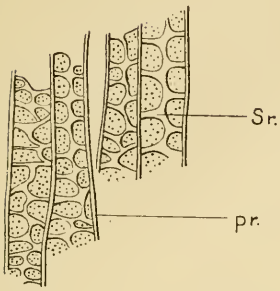
my.—myoneme.

pr.—primary ridges.

sr.—secondary ridges.

tr.—trichocysts.

um.—undulating membrane.



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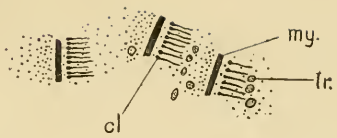

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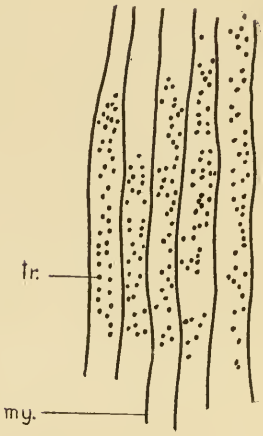

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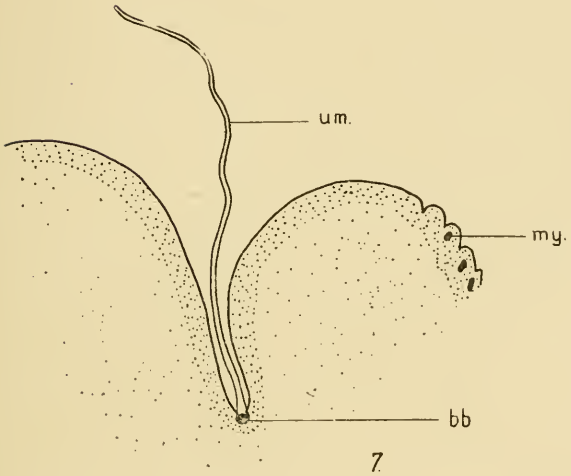

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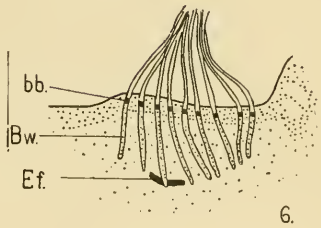

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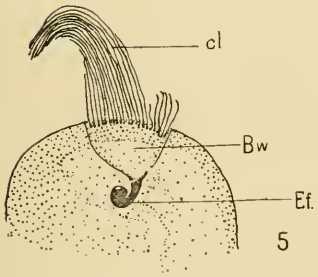

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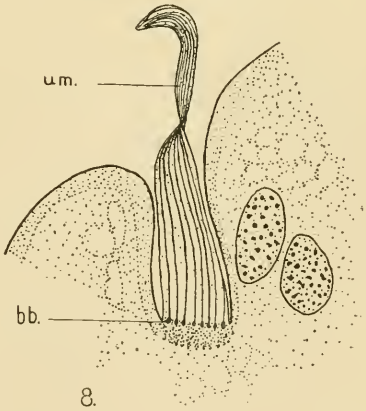

8.

INDEX TO VOLUME 3.

Synonyms in *Italics;* titles in **boldface.**

PAGE

Abeona minima 200
Additions to the Copepod Fauna of the San Diego Region 53
A Discussion of Species Characters in Triposolenia 117
Aesthetasks 3
Aetobatus californicus 174
Aglaophenia, corbula
  aperta 51
  apocarpa 51
  diegensis 48, 50, 51
  filicula 48, 50, 51
  inconspicua 50, 51
  octocarpa 51
  pluma 49, 50, 51
  struthionides 49, 50, 51
  Sexual Dimorphism in 47
Albula vulpes 176
Alepisaurus aesculapius 180
Allman, G. J. 48, 50, 51
Alopias vulpes 168
Amallophora 65, 66
  magna 66, 67
Amoeboid movements of Corymorpha 259, 292, 295
Amphidinium
  sulcatum 299–301
  aculeatum 301
  lacustre 301
  operculatum 301
Amphidoma biconica 311–312
  nucula 312
Amphilothus elegans 312
Amphisolenia 93–96, 98, 99, 117, 127, 133
  bifurcata 94–95
  palmata 315
  quinquecauda 95
  spinulosa 315
  thrinax 94, 95
  tripos 93, 125
Amphistichus argenteus 201
Anchovia compressa 177
  delicatissima 177

PAGE

Anemone,
The California Shore 41
Bunodactis xanthogrammica 41
Anisotremus davidsoni 196
Anoplopoma fimbria 216
Antennarius avalonis 247
Arbaciosa rhessodon 231
Archiconchoecia 15
Archiconchoecia striata 16, 30
Arietellus .....
major 74
setosus 74
Asterope 142
Astrolytes notospilotus 219
Asymmetry, significance of in Triposolenia 127–133
Atherinops affinis 187
insularum 187
Atherinopsis californiensis 186
Auchonopterus integripinnis 237
Augaptilus, fungifera 78
gibbus 78
magnus 78
rostratus 73
zetesios 183
Aulorhynchus flavidus 78
Averruncus sterletus 222
Axial parenchyma, development in Corymorpha 281, 294
as a skeleton 291
Balistes cinereus 204
polylepis 204
Bibliography of
Condylostoma paters 367
Copepoda 80–81
Corymorpha 297–298
Dinoflagellata 316–317
Marine Fishes 248–251
Nervous System of Copepoda 7
Ostracoda 150
Sexual Dimorphism in Aglaophenia 52
Triposolenia 110, 126
Biological Studies on Corymorpha II. The Development of the Egg of C. palma 253
Blennicottus recalvus 222
Bovard, J. F. 343
Brachyistius frenatus 200
Brama raii 193
Branchiostoma californiense 161
Bunodactidae 42

PAGE
Bunodactis 42
Bunodactis xanthogrammica 41, 43
Calanus robustior 77
Calycilepidotus spinosus 219
Caranx caballus 192
Carcharias lamiella 167
Catulus uter 163
Caulolatilus princeps 230
Central nervous system of Diaptomus 5
Ceratium 95, 98, 133, 299
Ceratium arcuatum 307
  californiense 299, 302
  carriense 305, 307
  eugrammum 308
  furca var. baltica 302
  fusus 133
  gallicum 302–303
  hexacanthum 305
  hundhauseni 307
  inclinatum 303
  inflexum 305
  longissimum 305
  macroceros 302–305
  macroceros deflexum 304
  mollis 304–305
  ostenfeldi 305
  patentissimum 96, 307
  recurvata 307
  reticulatum 305–306
  reticulatum spirale 305
  schranki 306
  strictum 133
  teres 308
  tripos arcuatum 306
  (*tripos* var.) *arcuatum* 306
  tripos flagellifera forma *augusta* 305
  tripos var. *inequale* 305
  tripos lunula 306
  tripos macroceros 302
  tripos var. *macroceras* 302
  tripos var. *macroceros* 302
  tripos macroceros forma longissima 304
  tripos patentissimum 303
  (*tripos* var.?) *volans* 305
  (*tripos* var.) *vultur* 305
  tripos volans 307
  volans 305
Chaenopsis alepidotus 240

PAGE
Chaetodipterus zonatus 204
Chilara taylori 240
Chilomycterus affinis 205
californiensis 205
Chimaera colliei 175
Chirundina 58
streetsi 59
Chitonotus pugetensis 218
Chromis punctipinnis 203
Citharichthys stigmaeus 246
sordidus 246
Cladocera of the San Diego Region 157
Clausocalanus 55
Clevelandia ios 229
rosae 229
Clinocottus analis 220
Clupanodon caeruleus 177
Clupea pallasii 176
Coincident distribution of related species 124–125
Cololabis brevirostis 183
saira 183
Conchoecia 17
ametra 149
clausi 23, 34
daphnoides 26, 38
giesbrechti 149
hyalophyllum 20, 32
lacerta 26
magna 19, 30, 32
mülleri 24, 34, 36, 149
oblonga 21
pacifica 21, 32, 34, 149
pellucida 18
ritteri 25, 36, 38, 149
spinirostris 18, 30
striata 24, 149
striola 149
tetragona 19
Condylostoma patens
Ectoplasmic structures 345
myonemes 346
cilia 347
membranellae 348
undulating membrane 349
buccal groove 349
General description 344
Locomotor movements 350
gliding 350

PAGE
in cut pieces 355
swimming 357
motor reaction 359
motor reaction in cut pieces 364
Occurrence 343
Structure 344
Contributions from the Laboratory of the Marine Biological Association of San Diego 13, 41, 47, 53, 93, 135, 157, 253, 299
Corbula
of Aglaophenia 51
aperta 51
apocarpa 51
calamus 51
diegensis 48, 50, 51
filicula 48, 50, 51
gracillima 51
inconspicua 50, 51
latirostris 51
octocarpa 51
pluma 49, 50, 51
struthionides 49, 50, 51
Corymorpha
palma, development of 253
Medusa 254
pendula 255
amoeboid movement 259, 292, 295
development of axial parenchyma 281, 294
development of fenestrated membrane 283, 294, 295
development of frustules 272, 293, 294, 295
development of gonosome 291, 294
development of peripheral canals 286, 294, 295
development of tentacles 264, 293, 294, 295
eggs and egg-laying 254
establishment of regions of body 261, 292, 294
growth 261, 294, 295
larva 258, 292
locomotion of larva 259, 292, 295
metamorphosis 278, 294, 296
morphogenesis 294
plasticity in development 294
polarity of larva 259, 292, 294
regions of body 261, 292, 294, 295
segmentation of egg 257
Cryptotrema corallinum 237
Cyanoscion nobilis 197
parvipinnis 198
Cyclops 5

Cylindroleberis 142
mariae 143, 154
oblonga 143
Cymatogaster aggregatus 200
Cypridinidae 139
Cypselurus californicus 183
Cytheridae 135
Damalichthys argyrosomus 203
Dasyatis dipterura 172
Development of Corymorpha 253
De Vries 124
Diaixis 65
Diaphus theta 179
Diaptomus 2
Dimorphism in Aglaophenia, Sexual 47
Dinoflagellata of the San Diego Region. II. On Triposolenia, a new Genus of the Dinophysidae 93–116
III. Descriptions of new Species 299–340
Dinophysidae 93–96, 101, 117
Dinophysis 94–96, 100
Dinophysis acuta 315
diegensis 313–314
ellipsoides 314
homunculus 313–314
rotundata 315
sacculus 315
Disseta 71
grandis 72
palumboi 72
Distribution of related species of Triposolenia 124–125
Echeneis remora 230
Eggs and egg laying of Corymorpha 254
Embiotoca jacksoni 201
Embryx crassilabris 240
Engraulis mordax 177
Enophrys bison 220
Eopsetta jordani 242
Eptatretus stouti 161
Esterly, C.O. 1, 53
Etrumeus micropus 176
Euchaeta antarcticus 78
austrina 78
californica 60, 61, 64
dubia 63
flava 60, 64
glacialis 78
norvegica 64
oceana 78
propinqua 61, 62, 64

PAGE
spinifera 62
tenuis 61, 63
tonsa 64
Euchirella 58, 59
carinata 78
curticauda 59
var. atlantica 59, 78
Eucinostomus californiensis 196
Evadne tergestina 157
Eximia rubellio 221
Exocœtus californicus 183
Fenestrated membrane of Corymorpha 283, 294, 295
Frustules, development in Corymorpha 293, 294, 295
Fundulus parvipinnis 181
Furcal bristles of Cyclops 5
Gaetanus 56–57
armiger 56, 57
brevicornis 56, 57
caudani 57, 58
clarus 57, 58
denticulatus 78
major 57, 78
miles 56, 57
Gaidius 56, 58
Galeorhinus zyopterus 166
Galeus californicus 163
zyopterus 166
Genyonemus lineatus 199
Germo alalunga 189
macropterus 189
Gibbonsia elegans 232
evides 232, 234, 235
Gillichthys detrusus 227
guaymasiae 228
mirabilis 225
Girella nigricans 197
Glyptocephalus zachirus 246
Gobiesox papillifer 231
rhessodon 231
Gobionellus sagittula 224
Gobius dalli 224
nicholsii 223
sagittula 224
zebra 223
Gonosome of Corymorpha 291
development 294
Gonyaulax pacifica 308–309
Growth in Corymorpha 261, 294, 295

PAGE
Gymnosarda pelamis 188
Gymnothorax mordax 175
Gyropleurodus francisci 161
Halichoeres semicinctus 204
Halocypridae 15
Halocypris 13, 149
clausii 23
dubia 27
var. *minor* 27
pelagica 27
Heterocapsa pacifica 299, 301
triquetra 301
Heterodinium 133
Heterodontus francisci 161
Heterorhabdus longicornis 77
spinifrons 77
Heterostichus rostratus 232
Hexagrammos asper 229
Hippoglossina stomata 242
Hippocampus ingens 186
Holconotus rhodoterus 201
Hydrolagus colliei 175
Hyperprosopon argenteus 200
agassizii 201
Hyporhamphus rosae 182
Hypsoblennius gilberti 238
gentilis 238
Hypsopsetta guttulata 244
Hypsurus caryi 202
Hypsypops rubicunda 203
Hypnus gilberti 228, 227, 229
Innervation of Copepoda
aesthetasks 3
olfactory clubs 3
rostral filaments 5
tactile bristles 4
Internal skeletal structures of Dinoflagellates 312
Iridio semicinctus 204
Isolation in evolution 124–125
Icelinus fimbriatus 218
quadriseriatus 219
Icelus australis 219
Jennings H.S. 129, 359
Juday, Chancey 135, 157
Key to species of Triposolenia 102
Kofoid, C.A. 2, 93, 117, 127, 299, 343
Labidocera 74, 76
aestiva 78

PAGE
jollae ... 74
kroyer ... 75
var. gallinsis ... 78
var. stylifer ... 75
nerii ... 78
pectinata ... 78
trispinosa ... 78
wollastoni ... 75
Lampanyctus townsendi ... 179
Lampris luna ... 192
regia ... 192
Larva of Corymorpha ... 258
Leiocattus hirundo ... 292
Lepidogobius lepidus ... 220
Lepidopus xanthusi ... 191
Leptocottus armatus ... 220
Leuresthes tenuis ... 186
Locomotion of Corymorpha ... 259, 292, 295
of Condylostoma patens ... 350
of Dinoflagellates ... 127
of Triposolenia ... 128–129
Loeb, J. ... 125
Lophothrix ... 65
frontalis ... 65
Lucicutia ... 71, 72
Lucioblennius alepidotus ... 240
Luvarus imperialis ... 192
Lycodapus fierasfer ... 241
Lycodonlis mordax ... 175
Lyopsetta exilis ... 241
Lythrypnus dalli ... 224
Macrostoma augustidens ... 178
Martin, A. ... 47
Medialuna californiensis ... 197
Medusa of Corymorpha ... 254
Menticirrhus undulatus ... 199
Merluccius productus ... 241
Metamorphosis of Corymorpha ... 278, 294, 296
Methylene blue ... 2
Metridia atra ... 70
gerlacheri ... 78
ignota ... 71
normani ... 78
princeps ... 69, 71
scotti ... 71
venusta ... 78
Microstomus pacificus ... 245
Mola mola ... 205

PAGE
Monops 75
Morphogenesis in Corymorpha 294
Morris, E.L. 159
Motor reaction 359
Movements of Condylostoma patens 350
Mugil cephalus 187
Mustelus californicus 163
Mutations 123–124
Myctophum californiense 179
Myliobatus californicus 174
Myodocopa 138
Naucrates ductor 191
Nannobrachium leucopsarum 179
Natural selection 122–124
Neoclinus blanchardi 236
  satiricus 236, 237
Nervous system of Copepoda 1
Note on the Halocypridae 149
Nutting, C.C. 51
Odontopyxis trispinosus 223
Oligocottus maculosus 222
  rubellio 221, 222
On the Significance of the Asymmetry in Triposolenia 127–133
Ophiodon elongatus
Ostracoda of the San Diego Region I. Halocypridae 13–38
Ostracoda of the San Diego Region II. Littoral Forms 135–158
Oxyjulis californica 204
Oxylebius pictus 217
Paracelinus hopliticus 217
Parachytheroma pedrensis 138, 152
Paralabrax clathratus 195
  maculatofasciatus 194
  nebulifer 194
Paralichthys californicus 242
Parophrys vetulus 245
Peprilus simillimus 193
Peridinium 95, 100
Peridinium erassipes 309
  depressum 309
  globulus 310
  minutum 310
  multistriatum 310–311
  pedunculatum 311
  rectum 311
  steini 311
Peripheral canals, development in Corymorpha 286, 294, 295
Perkinsia othonops 176
Phalacroma 95

PAGE
Phalacroma ultima 95
Phanerodon atripes 202
furcatus 202
Philomedes 139
lomae 141
longiseta 139
Pimelometopon pulcher 203
Piagyodus ferox 180
Platyrhinoides triseriatus 170
Plasticity, development of Corymorpha 294
Pleuronichthys caenosus 243, 244
decurrens 244
ritteri 243
verticalis 243
Pleoschisma 145
oblonga 145, 154, 156
Podocopa 135
Polarity of Corymorpha 259, 292, 294
Polydactylus opercularis 188
Pontellopsis 75
herdmani 78
occidentalis 76
villosa 77
Porichthys notatus 230
Poroclinus rothrocki 240
Posterocornia 97, 101
Prionace glauca 167
Pteroplatea marmorata 173
Quietula y-cauda 225, 227, 228, 229
Rabula aquae-dulcis 175
Racovitzanus 65
Raja inornata 171
rhina 170
Ramiciformia 97, 101
Rathbunella hypoplecta 230
Regalecus russelli 191
Regions of body of Corymorpha 261, 292, 294
Remora remora 230
Rhinobatus productus 168
Rhinogobius nicholsii 223
Rhinotriacis henlei 164
Rhocochilus toxotes 202
Rhombus simillimus 193
Rimicola eigenmanni 231
Ritter, W. E. 160
Roncador stearnsi 198
Rostral filaments of Diaptomus 5
Rudulinus boleoides 219

PAGE
Rutidermatidae 147
Rutiderma 147
rostrata 147, 156
Sarda chilensis 189
Sardinella caeruleus 177
Scaphocalanus 64, 65
acrocephalus 66
Schedophilus heathii 193
Sciaena saturna 198
Scolicithricella 65
Scolecithrix 64, 65
atlanticus 78
auropecten 67
brevicornis 78
chelifer 69, 78
cristata 65
frontalis 65
glacialis 78
hibernica 65
inornata 67
magna 66, 67, 68
minor 65
pacifica 78
securifrons 78
similis 78
subdentata 78
Scomber colias 188
japonicus 188
Scomberomorus sierra 190
Scorpaena guttata 215
Sebastodes
alascanus 205
alutus 208
atrovirens 209
auriculatus 213
aurora 209
ayresii 211
carnatus 214
chlorostictus 212
chrysomelas 214
constellatus 210
diploproa 209
elongatus 212
eos 211
flavidus 207
gilberti 214
gilli 212
goodei 206

PAGE
introniger 210
levis 213, 217
macdonaldi 208
melanostomus 210
miniatus 208, 219
mystinus 207
ovalis 208
pancispinis 207
pinniger 208
proriger 208
rastrelliger 213
rhodochloris 211
rosaceus 211
ruberrimus 210
rubrivinctus 213
rufus 207
rupestris 212
saxicola 209
semicinctus 209
serranoides 207
serriceps 215
umbrosus 210
vexillaris 214
zacentrus 212
Sebastolobus altivelis 206
Sense organs of Diaptomus 1
Segmentation stages Corymorpha 257
Seriola dorsalis 192
Seriphus politus 198
Sexual Dimorphism in Aglaophenia 47
Sexual reproduction in Dinoflagellates 121
Siphostoma arctum 185
auliscus 184
barbarae 185
californiensis 183
leptorphynchus 184
punctipinnis 184
Some observations on the Nervous System of Copepoda 1
Species Characters, nature of, in Triposolenia 117–120
table of, in Triposolenia 119
adaptive significance of 121–125
Spinocalanus
abyssalis 55, 79
longicornis 79
magnus 55, 79
major 55
Spheroides *annulatus politus* 205
politus 205

PAGE
Sphyraena argentea 188
Sphyrna zygaena 167
Squalus sucklii 168
Squatina squatina 168
Starks E. C. 159
Starksia holderi 237
Sterolepis gigas 193
Stolephorus compressus 177
Structure of Condylostoma patens 344–350
  Triposolenia 93–100
Sudis ringens 181
Summaries, Biological Studies on Corymorpha 292–296
  Nervous system of Copepoda 5–6
  Structure and movements of Condylostoma 366
Symphurus atrocaudus 247
Syngnathus arctus 185
  auliscus 184
  barbarae 185
  californiensis 183
  leptorhynchus 184
  punctipinnis 184
Synodus lucioceps 178
Tactile bristles of Copepoda 4
Taeniotoca lateralis 202
Tarandicthys cavifrons 218
  filamentosus 218
  tenuis 218
Tarletonbeania crenularis 179
  tenua 179
Tentacles, development in Corymorpha 264, 293, 294, 295
The California Shore Anemone, Bunodactis xanthogrammica 41–46
Tetrapterus mitsukurii 191
The Marine Fishes of Southern California 159–251
The Structure and Movements of Condylostoma patens 343–368
Thunnus thynnus 189
Torrey, H. B. 41, 47, 253
Trachurus picturata 192
Triakis semifasciatus 165
Triposolenia ambulatrix 96, 118-119
  bicornis 105–107, 118–120
  depressa 104–105, 118–120
  exilis 94, 108–110, 118–120
  fatula 96, 119
  longicornis 118–119
  ramiciforniis 94, 107–108, 110
  truncata 102–104, 117–120
Triposolenia, axial relations 94
  discussion of species characters in 117–126

PAGE
distribution of 101
generic description of 101
key to species of 102
morphology of 93–100
significance of asymmetry in 127–133
species of 102–110
Tylosurus exilis 182
Typhlogobius californiensis 229
Ulvicola sanctae-rosae 239
Umbina roncador 199
Urolophus halleri 172
Variations, fluctuating 120
Xanthocalanus 68
atlanticus 79
borealis 79
cristatus 69, 79
fragilis 79
giesbrechti 79
similis 79
simplex 79
subagilis 79
Xeneretimus latifrons 223
Xenistius californiensis 196
Xenochirus latifrons 223
Xerepes fucorum 239
Xestolebris 136
dispar 136, 152
Xiphias gladius 190
Xystreurys liolepis 242
Zalembius rosaceus 200
Zaniolepis frenatus 217
latipinnis 216
Zonogobius zebra 223
Zapteryx exasperatus 170

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